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METABOLISM STALLS FOR WETHERS AND STEERS

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AMONG the problems encountered in nutrient balance studies with large animals is the construction of metabolism equipment of simple design and operation which provides for the quantitative separation and collection of feces and urine. Metabolism cages for sheep have been described by Hodgson *et al.* (1935) and by Briggs and Heller (1940) as modifications of a cage designed by Forbes (1915) for metabolism studies with swine. Similar cages in common use, such as those employed by Burkitt (1940) and Sotola (1927) have a complete false floor of heavy wire mesh on which the animal stands. A removable screen of smaller mesh below the false floor catches the feces and permits the urine to run through to a sloped or funnel-shaped pan which directs the flow of urine into a collection bottle beneath the cage. To discourage the scattering of feed inside the cage, feed boxes are usually fastened on the outside and the feed made available by an opening for the animals' head at the front of the cage above the feed box. A stanchion is sometimes used for this opening and the animal stanchioned at feeding time as described by Maynard (1947). The cage may be large enough to permit considerable freedom of movement, which from the standpoint of comfort of the animal is probably an advantage.

A large cage of this type has the disadvantage that the feces are dropped over a wide area on the screen beneath the false floor and become exposed to contamination by urine as discussed by Dinning, Gallup and Briggs (1948). Further, feces which fail to pass through the false floor are trampled and the small particles then pass through both screens to the pan, where they contaminate the urine and obstruct its flow to the collection bottle. Feces collection bags fastened to the animal with a harness have been used to overcome this difficulty with wethers, such as those used by Forbes *et al.* (1937) and McCall, Clark and Patton (1943).

Obstructions such as the fine mesh of the second screen cause some splattering and spread of urine, and the size of the pan and its degree of slope allows the urine to spread over considerable surface. These conditions promote evaporation losses and fermentation of urine, thus decreasing the accuracy of collections enough to account for large errors in balance data.

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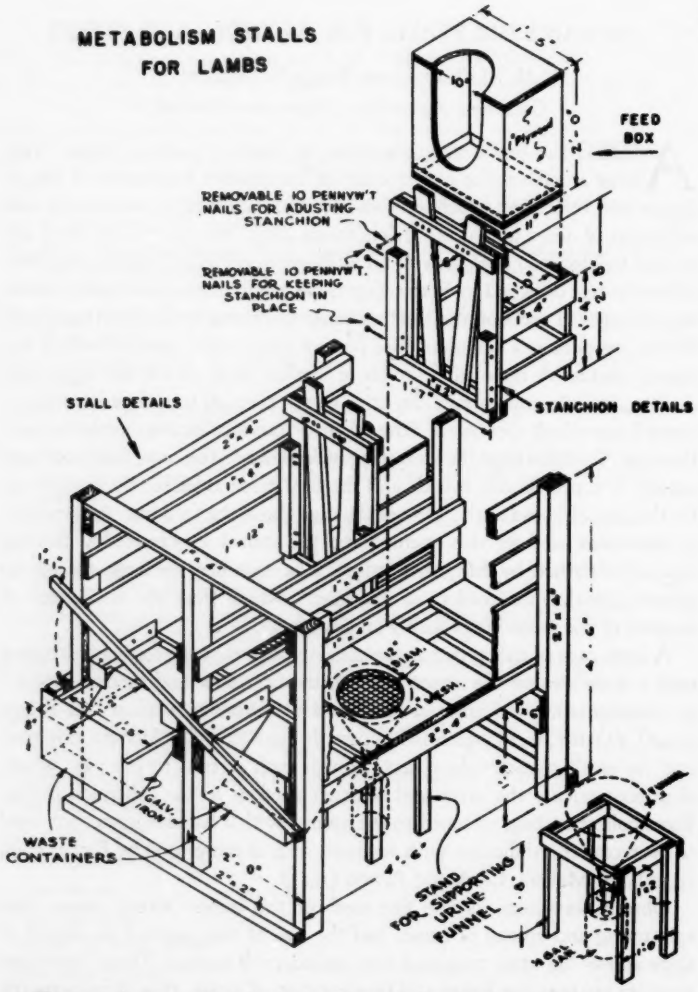

Figure 1. A perspective of a two-unit metabolism stall for wether lambs.

For example, in nitrogen balance trials with mature sheep whose total daily excretion of nitrogen may amount to 10 gm. while their retention may equal about 1 gm. per day, an error of 50 percent in retention values will result from a 5 percent error in collection.

Description of Stalls

The construction of a two-unit stall for wether lambs which has proven satisfactory in nitrogen and mineral balance studies is shown in figure 1. The lambs are stanchioned at all times during collection periods. The length of the stall may be adjusted by sliding the feed box and stanchion forward or backward as indicated in the diagram. The width may be decreased by setting in false sides. The feed boxes, which are removed and replaced by water containers after each feed, are designed to prevent scattering.

The wooden floor of the stall does away with the need of a closely woven heavy wire screen to support the weight of the lamb. Thus, urine is voided directly into the collection bottle with minimum exposure to collecting surfaces. A small screen in the neck of the glass funnel acts as a guard against contamination with foreign material. Once the stall is adjusted to the size of the lamb there is no detectable loss of voided urine.

The feces are collected without loss and without contamination in metal trays which fit at the rear of the stall with their front edges flush with the floor. The sloped front of the tray discourages the lambs from stepping back into the feces. The trays are light in weight and are easily emptied and cleaned.

A modification of the lamb stall has been made in constructing metabolism stalls for steers. These stalls also are made in pairs. The uprights of the stall are 4 in. round posts. The dimensional lumber used in construction is 2 in. $\times$ 4 in. and 2 in. $\times$ 6 in. instead of one-inch material. The stalls, including stanchion, feeder and gutter box, have an over-all length of approximately 8 feet, each stall proper being 4 ft. long and 2 ft. wide. The stanchion feeders are 4 ft. high and 28 in. deep. They are not removable but may be easily adjusted to lengthen or shorten the stall according to the size of the steer by removing the bolts which fasten the feeders securely to the sides off the stalls. The upper half of the front side of the feeder is hinged for ease in feeding. Water is provided in buckets twice daily.

Urine is collected by means of a rubber funnel[2] strapped to the steer with a harness and connected to a rubber hose leading to a 3-gallon bottle beneath the false floor of the stall. A 1-in. hole drilled in the solid wood floor accommodates the hose. A table clamp fastened to the hose just beneath the floor prevents its being pulled from the bottle.

[2] The funnels were made by the Davol Rubber Co., Providence 2, Rhode Island.

The gutter boxes which catch the feces are made of clear 2-in. lumber. They are 13 in. from front to rear and 9 in. deep, and each box extends the full width of each stall. They are set several inches below the false floor, the space between the flooring and the top of the box being closed by a canvas flap. The steers soon learn to avoid stepping back and down into the gutter boxes if the boxes are lowered a sufficient distance. The feces are removed at frequent intervals during the day and placed in covered containers.

More accurate collections can usually be made by feeding the steers early in the morning, getting them on their feet several times during the day and again late in the evening and by frequent checking of the urine collection funnel. The steers soon adjust themselves to their environment and tend to standardize their habits.

Summary

A description is given of metabolism stalls for use in nutrient balance trials with wethers and steers. The stalls, which are built in pairs, provide for separate collections of feces and urine. The lamb stalls are illustrated by a drawing which gives dimensions and the details of construction.

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A STUDY OF VARIATIONS IN MUSCLES OF BEEF AND CHICKEN

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STRIATED muscles have not been particularly attractive research material for the histologist. Some attention has been given to the cellular aspects of the muscles in an attempt to determine structural details, especially of the myofibrils. The commonly accepted concept of the anatomy of striated muscles indicates that all muscles are similar, being sharply and distinctly divided into fasciculi by connective tissue which has both elastic and collagenous elements present. Thus, striated muscles have been considered as not showing great variation in morphology or individuality anatomically. Some authors have intimated that some variations do exist between some of the muscles. Bremer (1944) indicated that the connective tissue of the diaphragm contains an abundance of elastic fibers but that the muscles of the extremities are poor in elastic tissue, containing only fine internal fibers found especially in the perimysium externum. Maximow (1938) reported that the number of elastic fibers in the interstitial connective tissue varies with the type of muscle and is probably closely related with its functional peculiarities.

Investigators studying the tenderness problem in meat animals have hoped that anatomical structure of muscles would give them the clue to the basic factors affecting tenderness. Some workers (Lehman, 1907; Mitchell, 1928; Mackintosh, 1936) have explained the variations in tenderness on the basis of the differences in kind and amount of connective tissue present in the muscles. Correlations of tenderness differences in muscles with (1) fat distribution (Helser, 1930; Hankins, 1939), and (2) diameter of muscle fibers and muscle bundles (Moran & Smith, 1929; Brady, 1937) have been attempted. Ramsbottom, Strandine and Koonz (1945) and Ramsbottom and Strandine (1948) made comprehensive surveys of the chemical and tenderness variations of most of the important beef muscles.

The purpose of the present investigation was to determine and report the histological variations that occur in muscles and to show their relationship to chemical variations. A better understanding of microscopic structure and of chemical composition of these muscles may help to reveal the factors responsible for variations in tenderness.

Procedures and Methods

Fifty of the principal muscles comprising about 88 percent of the lean meat of the beef carcass were removed from four different carcasses and studied chemically, organoleptically, and histologically. In addition to the beef muscles, twelve of the largest muscles from twelve chickens were investigated. These twelve muscles comprised 70 percent of the edible meat of the bird. The chemical and organoleptic data on the beef muscles were reported by Ramsbottom *et al.* (1945, 1948).

Chemical analysis of the muscles included moisture, fat, protein, and pH determinations. For histological studies the tissues from each muscle were fixed in 10 percent formalin, dehydrated in alcohol and chloroform, and embedded in paraffin. The stains employed were Weigert's elastic connective tissue stain, Mallory's triple connective tissue stain, and Delafield's hematoxylin-eosin stain. The tissue distribution was noted and an estimation of the amount of elastic and collagenous connective tissue was noted. Larger pieces of muscle fixed in formaldehyde were sectioned with the freezing microtome and stained with Sudan III and gentian violet, to show the distribution of fat, and the general size and arrangement of the muscle bundles or fasciculi. Muscles were classified on the basis of the size and distinctiveness of the fasciculi and the amount of connective tissue surrounding them. A numerical evaluation or rating was given to each muscle on the basis of the relative amounts of elastic and collagenous fibers present in the muscle. Thus, large amounts rated 7 points, medium amounts 5, small amounts 3, and none 1.

The tenderness of both raw and cooked muscle was determined (1) by shearing on the Warner-Bratzler shear apparatus (1928), a column of meat one-half inch in diameter in the case of beef or the whole muscle in the case of chickens; and (2) by organoleptic ratings in blind tests using a committee of three skilled judges. Muscles were rated organoleptically on a scale of 1 to 10, a value of 10 indicating the most tender muscle, and a value of 1 indicating the least tender muscle.

Results

Chemical Variations in Muscles

In chickens the muscle pH measured 48 hours after slaughter was relatively constant ranging from 5.6 to 6.0. The fat varied from 1.3% in the pectoralis profundus muscle of the breast to 10.3% in the adductor muscle of the thigh. Moisture varied from 69.6% in the adductor to 75.1% in the biceps femoris of the thigh. In general, the amount of fat present was inversely proportional to the amount of moisture. The extremes in protein values were 19.9% and 25.0% in the semitendinosus and pectoralis pro-

fundus muscles respectively. There was no positive correlation between the tenderness of the chicken muscles and any of the chemical factors studied (figure 1).

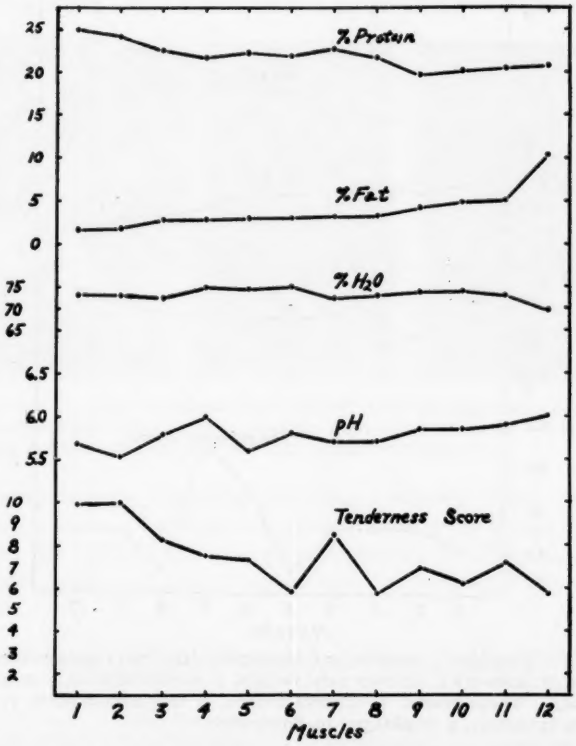

Figure 1. Variations in chemical and tenderness data from representative chicken muscles. Muscles are 1. pectoralis profundus, 2. pectoralis superficialis, 3. biceps brachii, 4. peroneus longus, 5. gastrocnemius, 6. biceps femoris, 7. triceps brachii, 8. semimembranosus, 9. semitendinosus, 10. quadriceps femoris, 11. gluteus, 12. adductor.

Similar results were reported by Ramsbottom *et al.* (1945 and 1948) for beef. The relationship in beef of chemical composition to tenderness is shown in figure 2. It appears that the chief causes of variation in tenderness are not pH, fat, total protein or mositure but rather the differences in the structure and arrangement of the constituent anatomical elements, the differences in structure within the muscle fibers, or both.

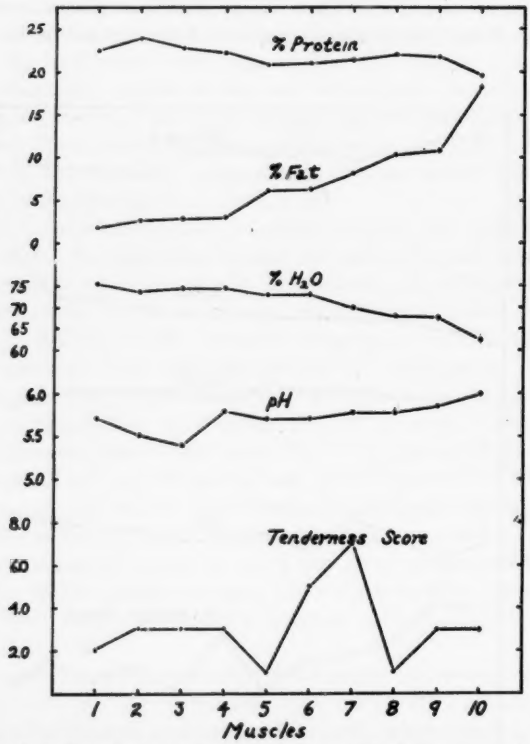

Figure 2. Variations in chemical and tenderness data from representative beef muscles. Muscles are 1. extensor carpi radialis, 2. semitendinosus, 3. semimembranosus, 4. biceps brachii, 5. internal oblique, 6. longissimus dorsi, 7. psoas major, 8. cutaneous, 9. diaphragm, 10. intercostals.

Histological Variations in Muscles

Cross sections of muscles taken anywhere in the muscle except at the extreme ends (origin and insertion) were rather uniform and presented a regular pattern or arrangement of muscle bundles and connective tissues. The cross-sectional patterns in a given muscle were fairly constant from animal to animal, although in the older animals more connective tissue was apparent between the bundles.

The histological patterns of different muscles were not alike, but varied in size and arrangement of the fasciculi (muscle bundles) as well as in the amounts and kinds of connective tissue elements in the perimysium. Beef

muscles such as the pectoralis superficialis (figure 3) had large and very distinct fasciculi with thick perimysia with many connective tissue fibers. Smaller fasciculi were observed in many muscles such as the brachialis (figure 3). In the iliacus muscle (figure 3) the perimysium was very thin and

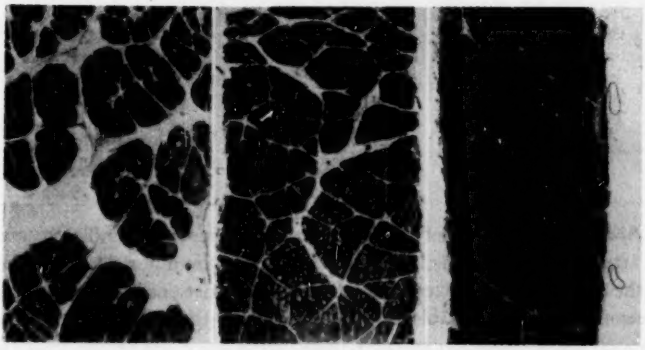

Figure 3. Pectoralis superficialis of beef (left) showing large distinct fasciculi; brachialis of beef (center) showing medium sized bundles; iliacus of beef (right) showing indistinct bundles and very little connective tissue. 2×.

with few connective tissue fibers, resulting in indistinct bundles and producing a muscle pattern of more uniform or homogeneous texture. Chicken muscles also differed from one another with respect to these bundles or fascicular patterns. Muscles thus had large, medium, small or indistinct bundles.

TABLE 1. CLASSIFICATION OF BEEF MUSCLES ON THE BASIS OF BUNDLE SIZE AND CONNECTIVE TISSUE PATTERN

Muscles with large distinct fasciculi and wide perimysium	Muscles with medium sized fasciculi and thinner perimysium	Muscles with small fasciculi and very thin perimysium	Muscles with indistinct fasciculi and very uniform texture
Brachiocephalicus	Brachialis	Biceps brachii	Adductor
Cutaneous	External oblique	Complexus	Intercostals
Deep pectoral	Latissimus dorsi	Diaphragm	Iliacus
Semitendinosus	Longissimus dorsi	Extensor carpi radialis	Intra-transversus colli
Sternocephalicus	Rectus abdominis	Gastrocnemius	Longissimus costarum
Superficial pectoral	Rhomboideus	Gluteus medius	Infraspinatus
Trapezius	Semimembranosus	Gluteus profundus	Multifidis dorsi
	Serratus ventralis	Gracilis	Pectineus
	Splenius	Internal oblique	Psoas major
	Tensor fascia latae	Rectus femoris	Psoas minor
	Transversus abdominis	Subscapularis	Teres major
	Vastus intermedius	Supraspinatus	Triceps brachii
	Vastus medialis	Vastus lateralis	

TABLE 2. CLASSIFICATION OF CHICKEN MUSCLES ON THE BASIS OF BUNDLE SIZE AND CONNECTIVE TISSUE PATTERN

Muscles with large distinct fasciculi	Muscles with small distinct fasciculi	Muscles with indistinct fasciculi
Biceps femoris	Adductor	Biceps brachii
Peroneus longus	Cruratis caudalis	Coraco-brachialis
Sartorius	Gastrocnemius	Gluteus superficialis
Semimembranosus	Gluteus medius	Pectoralis profundus
Semitendinosus	Gracilis	Pectoralis superficialis
Triceps brachii	Obturator externus	Pectineus
	Quadriceps femoris	Quadratus femoris
	Tensor fascia latae	Tibialis cranialis
	Trapezius	

Although all degrees of intermediate arrangements of bundles occurred, an attempt was made to classify the beef and chicken muscles on the basis of the cross-sectional pattern produced by the variations in the bundles and the connective tissue (tables 1 & 2). In general, the muscles with distinct fasciculi and abundant connective tissue were much less tender than those with smooth or homogeneous patterns. In some cases it was not possible to obtain a good correlation between tenderness and muscle pattern indicating that this factor is not the only one which influences tenderness.

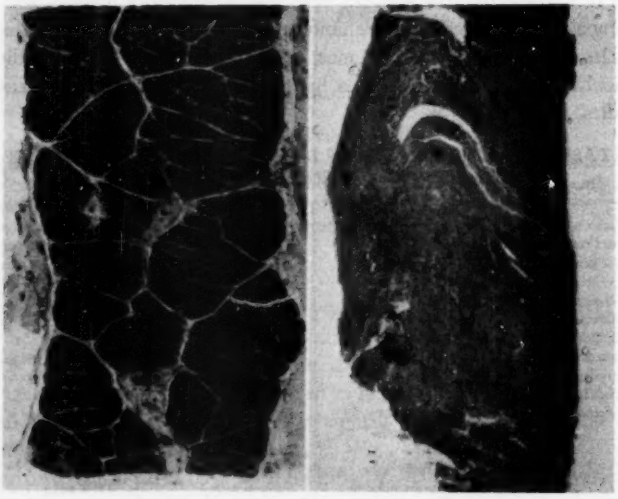

Figure 4. Deep pectoral of beef (left) compared to pectoralis profundus of chicken, showing differences in fasciculi. 3×

Not only were there variations in muscles within a given species but also in homologous muscles from different species. In figure 4 the deep pectorals of beef and chicken are compared, showing that in beef this muscle is sharply divided into distinct fasciculi by thick sheets of connective tissue whereas in the chicken the connective tissue is much reduced and the fasciculi are

TABLE 3. VARIATIONS IN THE RELATIVE AMOUNTS OF COLLAGENOUS CONNECTIVE TISSUE IN BEEF MUSCLES

Muscles with large amounts	Muscles with medium amounts	Muscles with small amounts
Biceps brachii	Adductor	Gluteus medius
Brachiocephalicus	Biceps femoris	Iliacus
Complexus	Brachialis	Intercostal
Cutaneous	Diaphragm	Longissimus dorsi
Deep pectoral	Extensor carpi radialis	Multifidis dorsi
Deltoid	Glutèus profundus	Pectineus
External oblique	Gracilis	Psoas major
Gastrocnemius	Infraspinatus	Rectus femoris
Latissimus dorsi	Internal oblique	Teres major
Obturator externus	Intratransversus colli	
Obturator internus	Longissimus costarum	
Omotransversarius	Psoas minor	
Semitendinosus	Rectus abdominis	
Sternocephalicus	Rhomboideus	
Superficial digital flexor	Sartorius	
Superficial pectoral	Semimembranosus	
Trapezius	Serratus ventralis	
	Splenius	
	Subscapularis	
	Supraspinatus	
	Tensor fascia latae	
	Teres minor	
	Transversus abdominis	
	Triceps brachii	
	Vastus intermedius	
	Vastus lateralis	
	Vastus medialis	

not apparent. In chicken this muscle is one of the chief muscles of the tender white meat, while in beef it is part of the brisket, which is much less tender and is used in making corned beef.

Muscles also varied in the relative amount of collagenous fibers present in the perimysia. In table 3 the beef muscles have been grouped according to whether a large, medium, or small amount of collagenous connective tissue is present in the internal perimysium.

Muscles differed also in the number of elastic fibers and in the size of these fibers. Adjacent muscles, for example the semimembranosus and semi-

tendinosus differed greatly, the latter (figure 5) having numerous large fibers, and the former being practically devoid of these fibers. In many beef muscles, e.g. the psoas major, it was difficult to find any elastic connective tissue outside of that found in the arteries and arterioles, while in other muscles heavy masses of elastic connective tissue were present. A classification of beef muscles on the basis of elastic connective tissue is shown in

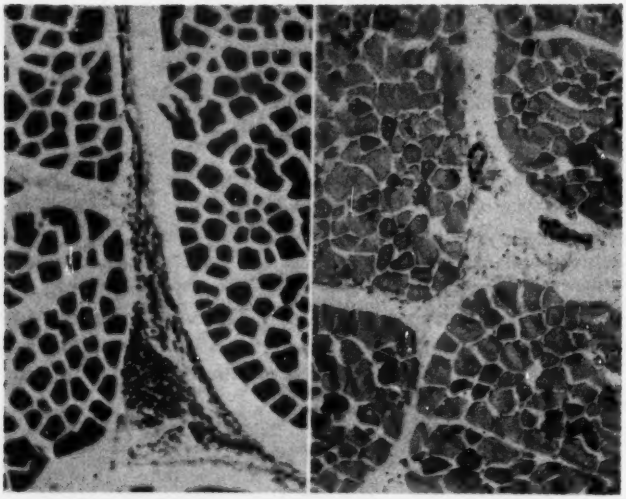

Figure 5. Semitendinosus muscle (left) of beef showing large masses of elastic fibers in the perimysium, and the semimembranosus (right) almost devoid of elastic connective tissue. 75×

table 4. In general, the loin and gluteal muscles had few elastic fibers, while the shoulders, neck, and abdominal regions had large numbers of elastic fibers. This variation in elastic connective tissue is consistent from carcass to carcass within a species, but does not always have phylogenetic significance. Elastic fibers in chicken muscles were much reduced in size and number when compared with beef muscles. In general, it may be stated that muscles having little connective tissue (especially elastic fibers) were more tender than those with large amounts.

A numerical tenderness rating for each muscle on the basis of the relative amounts of elastic and collagenous fibers was obtained by adding the numerical evaluation (1, 3, 5, or 7) for elastic fibers to the numerical evaluations (1, 3, 5 or 7) for the collagenous fibers. A comparison of this histological tenderness rating with the shear readings or organoleptic ratings of the

muscles showed a general positive correlation, muscles with high histological ratings having high shear readings (Ramsbottom *et al.*, 1945). The correlation coefficient for these data on all of the beef muscles studied was 0.7 which is statistically significant showing that connective tissue is a significant factor influencing tenderness but not the only factor.

TABLE 4. VARIATIONS IN THE RELATIVE AMOUNTS OF ELASTIC CONNECTIVE TISSUE IN BEEF MUSCLES

Muscles with large amounts	Muscles with medium amounts	Muscles with small amounts
Cutaneous	Biceps brachii	Adductor
External oblique	Biceps femoris	Brachialis
Latissimus dorsi	Complexus	Brachiocephalicus
Semitendinosus	Deep pectoral	Diaphragm
	Deltoid	Gastocnemius
	Extensor carpi radialis	Gluteus medius
	Gracilis	Gluteus profundus
	Internal oblique	Iliacus
	Obturator externus	Infraspinatus
	Obturator internus	Intercostal
	Omotransversarius	Intratransversus colli
	Rectus abdominis	Longissimus costarum
	Rhomboidus	Longissimus dorsi
	Sartorius	Multifidis dorsi
	Serratus ventralis	Pectineus
	Splenius	Psoas major
	Superficial pectoral	Psoas minor
	Suprasinatus	Rectus femoris
	Transversus abdominis	Semimembranosus
	Trapezius	Sternocephalicus
	Vastus lateralis	Subscapularis
		Superficial digital flexor
		Tensor fascia latae
		Teres major
		Teres minor
		Triceps brachii
		Vastus intermedius
		Vastus medialis

Discussion

As a result of the present and previous studies, it is apparent that there is little correlation between tenderness of the muscles and the chemical factors which were studied. Mitchell (1927) found a correlation between the collagen nitrogen and the toughness of various muscles, and this is in agreement with our findings on collagenous connective tissue distribution. Generally, it has been considered that fat is likely to influence tenderness to an important degree. This was not confirmed in the present study.

A correlation was found between the histological structure and the tenderness of the muscle; the muscles which had the larger amount of total connective tissues showed the higher shear readings and the lower organoleptic ratings. This connective tissue in the less tender muscles distinctly divided the muscles into prominent fasciculi. On the basis of the size of the fasciculi and the amount of connective tissue, it was possible to classify beef and chicken muscles.

As revealed by the photomicrographs and by the tables, the results demonstrated that a great variation exists histologically between the different muscles in the same carcass. Homologous muscles in the same species were generally similar from carcass to carcass. A comparison of homologous muscles in the chicken with those in beef made it evident that there is a large phylogenetic variation in homologous muscles. For example, in the chicken, the pectoralis superficialis had very little connective tissue and very little fat. In the beef, on the other hand, this homologous muscle had an abundance of fat and connective tissue, chiefly of the collagenous type, which was distributed so as to make the fasciculi appear very prominent.

Muscles showed great variation in the size and amount of collagenous fibers present in the perimysium. In general, the muscles with large collagenous fibers were the toughest, although prolonged cooking gelatinized and softened these fibers. These tenderness variations are in agreement with the chemical analyses for collagen made by Mitchell (1927).

Elastic fiber distribution varied from muscle to muscle, and was very scarce in chicken muscles. The cause of the varied distribution of elastic fibers in muscles is still an unsettled problem. Maximow (1938) and LeGros Clark (1939) suggest that the amount of elastic connective tissue is related to the tension or functional stress to which a muscle is subjected. It is also known that the length of time during which a muscle is subjected to tension varies. Some muscles such as the longissimus dorsi are subjected to a continuous weak tension (tonus) wheras other muscles like the anti-gravity muscles of the leg, undergo weak intermittent contractions, while the animal is standing still, but very strong contractions during active work. A muscle such as the diaphragm contracts moderately and at regular intervals throughout the life of an animal thus illustrating another type of behavior. This variation in duration and intensity of work performed by muscles is definitely reflected in the anatomical or histological architecture of the muscle. As far as we have been able to determine, no satisfactory method has been devised to measure the amount or type of stress to which each individual muscle is subjected as it functions in the living animal and consequently no definite correlation can as yet be made between the amount of elastic tissue in a muscle and the strain to which it is subjected.

It has been determined that most muscles become less tender upon being heated quickly to 170° F. (Ramsbottom *et al.*, 1945), although the collagenous connective tissue by itself became more tender upon cooking, due to gelatinization. It, therefore, becomes obvious that factors other than connective tissue affect tenderness of cooked muscles. It appears likely that the proteins and other constituents in the muscle fibers play an important role in determining the character of the cooked muscles. It may be suggested that such factors as coagulation and denaturation of the muscle fiber proteins, together with shrinkage and hardening of the muscle fibers, may account for the increase in toughness during some types of short cooking. Further work is needed to determine precisely the specific factors responsible for this toughness in the cooked muscles. Future tissue studies with the electron microscope of the ultra-microscopic structure of the fibrils and the protein chains within the muscle fibers may reveal information which will help in elucidating the problem of toughness of meat.

Meanwhile, the scientist in the food industry has at his disposal chemical and histological information on the variability in muscles in different parts of the animal carcass.

The results of the present study make it quite apparent to the histologist that striated muscles of vertebrates differ greatly in their anatomical structure. These muscles, in fact, are so dissimilar that with some experience a microscopist or histologist should be able to identify many of the muscles of the carcass from properly prepared histological sections.

Conclusions

1. A chemical and histological study of 50 of the principal beef muscles and 12 of the principal chicken muscles has demonstrated that variability exists between muscles within the same species and in different species.

2. Variations in pH, protein, fat, and moisture content were present but did not correlate with tenderness values of the muscle.

3. Variations in the size and arrangement of fasciculi and the connective tissue were apparent when the muscles were cut transversely.

4. Fascicular patterns were constant for a given muscle within a species, but were different from different muscles of the same species and different for homologous muscles of different species.

5. Both elastic fibers and collagenous fibers varied from muscle to muscle with respect to their size and quantity.

6. There was a general correlation between the fasciculi-connective tissue patterns and the tenderness measurements of the muscles, tenderness being associated with muscles having indistinct fasciculi.

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MOLD CONTROL IN STORED CURED PORK[1]

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TRIMMING losses, off flavors, and unattractiveness due to mold are still problems in the storage of cured meats. Most of the information concerning mold control comes from either unpublished or unorganized research. One of the approaches toward mold control on cured meats has been to apply a material to act as a cover on the outside of the cured cuts which might inhibit mold growth and retain the natural quality of the meat. It is with this approach that we have experimented during the past three years. This is a progress report of that work.

Experimental Procedure

Treatments

The work was started with 6 groups of brine-cured pork cuts. The cuts were smoked and then stored at refrigeration temperatures between 40 and 45° F. before treatment was started. One ham, picnic shoulder and bacon made up each group except in the preliminary series of 1946.

The 1946 trials were set up to include calcium propionate, a special grade of oat flour, linseed oil, lard, and lard plus linseed oil as the materials applied to the outside of the cured cuts. The same materials were used during 1947, but during 1948 two proprietary waxes, lard plus a special grade of oat flour and lard plus a commercial antioxidant were used. These materials were rubbed over the outside of the cuts and any excess was removed. The cuts were stored at 50 to 55° F., and a humidity of 75 to 85 percent.[2] The high humidity was maintained in order to encourage mold growth. The weight of the cuts was taken at the beginning and end of the experiment except during the preliminary series when no weights were taken.

The storage period varied in length and was determined by the time required for mold growth to appear on the controls and when flavor tests could be made. All cuts in 1946 were stored for 95 days. The bacons and picnic shoulders were stored 116 days and the hams 275 days in 1947. In 1948 all cuts were stored for 124 days. At the close of the trials the amount of mold growth was observed and palatability tests were made on each lot of meat.

[1] Published with the approval of the director of the Wisconsin Agricultural Experiment Station.
[2] No temperature or humidity control for two weeks of 1948 series.

Cooking Methods

The experience with preparation and scoring during 1946 has indicated to us that frying thin slices or simmering larger pieces was not a good method of cooking preparation. Grinding the whole picnic shoulder cut or the outer 1½ inches on the lean side of the ham and baking the ground meat in a loaf was more satisfactory. Therefore, the procedure for 1947 and 1948 was to bake a mixture of 300 grams of ground meat, 50 grams whole egg, and ½ cup water for 45 minutes at 350° F. The baked meat was then thoroughly mixed with a fork and about a tablespoonful given to each judge for sampling. It was deemed wise to attempt to eliminate the extreme salt flavor by overnight soaking. The ground meat, formed into a pat 4 inches by 8 inches in size was soaked in 2 cups of water, of which 1½ cups were discarded prior to cooking.

The bacon cut ⅛ inch thick was heated to a light brown color on racks of a shallow pan in on oven at 350° F. The bacon was cut and/or crumbled into small pieces, the entire sample mixed and spoonfuls of hot bacon given to the judges.

Judging Method

For flavor testing, each treatment sample was paired with a control, one or the other at random being offered to the scorers in duplicate (thus the scorers had three samples to study). The judges were asked to indicate which were the duplicates and whether they preferred the duplicates or the single. The judging procedure, thus, was a differential taste test according to the method of Bengtsson and Helm (1946). The judges were chiefly senior or graduate students in Experimental Cookery, the number varying from 16 to 24. Different persons composed the panel in different years. The flavor data were analyzed statistically according to a chi-square method or a modified chi-square method as described by Snedecor (1947), and Roessler *et al.* (1948).

Results

Mold Control

The relative amounts of mold growth are given in table 1. Control lots at the completion of each trial were heavily covered with mold and the surface of the meat was very hard and dry.

The special grade of oat flour did retard mold growth to some extent. The most noticeable protection came during the first part of the storage period.

Lard alone, lard plus linseed oil, lard plus a commercial antioxidant and lard plus a special grade of oat flour did not retard mold growth appreciably, but appeared to offer good protection from mold penetration into the meat

itself. The mold was in the lard covering and was thereby easily removed. Here again mold did not appear as soon as on the control lots.

Calcium propionate proved to be very effective in retarding mold growth. Only after several months' storage did the mold appear on the cuts in these lots.

Proprietary wax No. 1 had the property of becoming brittle at the storage temperatures used. This wax offered good protection against mold until

TABLE 1. MOLD GROWTH AND MOISTURE LOSS

Year	Cut	Treatment	Mold Growth	% Moisture Loss
1947	Ham	Control	Heavy	19.2
	Ham	Special grade oat flour	Very heavy	16.9
	Ham	Ca propionate	Slight	13.3
	Ham	Lard	Heavy	6.7
	Ham	Linseed oil and layer of lard	Heavy	9.8
	Ham	Linseed oil	Heavy	16.8
1948	Ham	Control	Heavy	9.1
	Ham	Lard—10% special grade oat flour	Heavy	4.0
	Ham	Lard—commercial antioxidant	Heavy	4.2
	Ham	Proprietary Wax No. 1	Medium	2.3
	Ham	Proprietary Wax No. 2	None	.8
1947	Shoulder	Control	Heavy	18.9
	Shoulder	Special grade oat flour	Medium	17.7
	Shoulder	Ca propionate	Very slight	17.5
	Shoulder	Lard	Medium	8.3
	Shoulder	Linseed oil and layer of lard	Medium	8.3
	Shoulder	Linseed oil	Slight	20.6
1948	Shoulder	Control	Heavy	15.5
	Shoulder	Lard—10% special grade oat flour	Heavy	5.7
	Shoulder	Lard plus commercial antioxidant	Heavy	6.3
	Shoulder	Proprietary Wax No. 1	Medium	4.9
	Shoulder	Proprietary Wax No. 2	None	0.0
1947	Bacon	Control	Heavy	11.4
	Bacon	Special grade oat flour	Slight	8.1
	Bacon	Ca propionate	Very slight	13.4
	Bacon	Lard	Medium	3.3
	Bacon	Linseed oil and layer of lard	Medium	1.9
	Bacon	Linseed oil	Slight	9.8
1948	Bacon	Control	Heavy	9.7
	Bacon	Lard—10% special grade oat flour	Medium	3.2
	Bacon	Lard—commercial antioxidant	Medium	6.2
	Bacon	Proprietary Wax No. 1	Medium	4.6
	Bacon	Proprietary Wax No. 2	None	2.7

breaks appeared in the wax. At the end of the trial about one fourth of the ham and shoulder was protected from mold.

The second proprietary wax (No. 2) had the property of remaining soft and pliable at the storage temperature. This wax offered excellent protection and no mold growth was in evidence on the cuts treated in this manner.

Shrinkage During Storage

Shrinkage through moisture loss does not have the economic importance in stored meats on farms as in commercial storage. Yet, to allow a piece of meat to lose moisture might bring about changes in the meat which may affect its quality.

Some of the materials protected the cuts from moisture loss better than others as shown in table 1. As one might expect, lard alone or in combination with other materials offered good protection.

The first proprietary wax, although brittle at room temperature, prevented excessive moisture loss, while the second wax, soft and pliable at the storage temperature, reduced the losses to a negligible amount. It would appear that this wax gave an air-tight seal to the cuts.

In general, picnic shoulders shrank more during storage than the hams or bacons. This might be explained by the larger ratio of lean surface to weight in shoulders as compared to hams and the larger ratio of lean to fat as compared to bacons. Hams lost a larger percentage of weight than bacons, perhaps again due to the larger ratio of lean to fat. Even greater shrinkage might be expected in home-cured meats, since humidity was controlled at a higher level than under ordinary farm storage conditions.

Flavor Tests

The data on flavor tests for hams and bacons are presented in table 2. It is evident that only one of the treatments on hams, the covering with wax No. 2, gave a significant improvement in flavor. Hams treated with calcium propionate, linseed oil, or lard with oat flour or antioxidant, were definitely disliked by the scorers. The cuts treated with the soft proprietary wax No. 2 gave the most favorable results. Next to this treatment in effectiveness was the application of oat flour.

Among the bacon samples, covering with lard alone or linseed oil and lard gave significantly poorer acceptance by the judges. Possibly increased rancidity accounted for some of the off-flavor. The one cut of bacon given a soft proprietary wax wrap had a peculiarly sweet, fruity flavor to which all except one judge objected.

The flavor tests on shoulders were analyzed in the same manner but are not reported in detail. For only two treatments on shoulder cuts were the

judges able to distinguish a statistically significant number of duplicates. As for hams, the use of calcium propionate was rated statistically inferior to the control in flavor acceptance. The use of proprietary wax No. 2 gave a product which the scorers could distinguish from the control and which they preferred but the difference was not significant. The use of the entire shoulder cut probably diluted any off-flavor to such an extent that judges did not distinguish differences on shoulders as sensitively as on hams.

TABLE 2. FLAVOR TESTS ON CURED HAM AND BACON

Year	Cut	Treatment	No. of Judges	No. of Correct Duplicates	Number[1] Preferring	
					Control	Treated
1947	Ham	Oat flour	24	22**	9	13
1947	Ham	Ca propionate	23	18**	18**	0
1947	Ham	Lard	24	16**	7	9
1947	Ham	Linseed oil and lard	22	15**	5	10
1947	Ham	Linseed oil	22	15**	11	4
1948	Ham	Lard and oat flour	21	19**	18**	1
1948	Ham	Lard and antioxidant	20	19**	15*	4
1948	Ham	Proprietary wax No. 2	20	15**	3	12*
1947	Bacon	Oat flour	20	6		
1947	Bacon	Ca propionate	17	6		
1947	Bacon	Lard	17	12**	10*	2
1947	Bacon	Linseed oil and lard	18	18**	18**	0
1947	Bacon	Linseed oil	20	9		
1948	Bacon	Lard and oat flour	21	12**	6	6
1948	Bacon	Lard and antioxidant	20	13**	4	9
1948	Bacon	Proprietary wax No. 2	20	19**	19**	0[2]

[1] Based on judges who identified duplicates.
[2] Many judges commented on a peculiar, fruity flavor.
* $=P \leq 0.05$.
** $=P \leq 0.01$.

A consideration of the technique of testing leads to the observation that judges may, on the basis of color or juiciness as well as flavor, be able to pick out the duplicates. Yet, while distinguishing a difference, the scorers are, in some cases, divided in their preferences. The strong salty flavor of cured pork makes it more difficult to distinguish degrees of rancid, moldy or musty flavor. However sufficient promise is shown to warrant further tests by certain treatments especially the wax covering of hams and shoulder cuts, the application of lard and antioxidant on bacons.

Conclusions

1. Calcium propionate and the pliable proprietary wax used were excellent inhibitors of mold growth. Judges objected to the flavor of calcium propionate on hams and shoulders and of the bacon covered with the pliable wax.

2. Lard alone or in combination with other materials allowed mold growth, but the mold embedded in the lard was easily removed. Flavor of cuts treated with lard or lard and linseed oil were rated poorer than controls. The combination of lard with a special grade of oat flour or antioxidant needs further flavor testing.

3. A special grade of oat flour and linseed oil gave only moderate protection against mold. The oat flour gave a more acceptable flavor.

4. Loss of weight was negligible in the lot treated with the pliable proprietary wax. Losses were greatly reduced in the lard-treated lots as compared to the controls.

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EFFECT OF THIOURACIL ON RATE AND EFFICIENCY OF GAINS OF SWINE[1]

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USING the paired-feeding, trio-feeding, group-feeding and individual-feeding techniques, 109 fattening swine were fed to determine (1) a practical optimum level of thoiuracil (2-thio-6-oxypyrimidine) to include in the ration and (2) the effect of this level on rate and efficiency of gains. In these studies the optimum level of thiouracil to include in the ration of fattening swine weighing 140 to 180 pounds initially appeared to be about 0.15 percent. The most important effect of feeding this compound to fattening swine was the increased feed efficiency secured.

Since MacKenzie, MacKenzie and McCollum (1941) demonstrated that sulfanilylguanidine suppressed thyroid action in the rat, considerable interest has developed in the feeding of thiouracil and related goitrogenic compounds to farm animals to study the effect on rate and efficiency of gains. The discordant results reported to date indicate a need for more information on the capabilities and limitations of thiouracil in swine feeding (Muhrer and Hogan, 1945; McMillen, Reineke, Bratzler and Francis, 1947; William, Loosli, and Klosterman, 1946; Asdell, 1947; Muhrer, Warner, Palmer and Hogan, 1947, Vander Noot, Reece and Skelley, 1947, 1948; Beeson, Andrews, Wiltz and Perry, 1947; Acevedo, Schweigert, Pearson and Dahlberg, 1948: and Hale, Robertson, Lyman and Wyatt, 1948).

The object of the first phase of the study was to determine a practical optimum level of thiouracil to include in the ration for fattening swine. The object of the second phase of the investigation was to study the effect on rate and efficiency of gains of adding 0.15 percent thiouracil (optimum level in the first phase) to a control ration under conditions of (1) equalized feed intake, (2) full-feeding and (3) feeding for equalized gains.

Experimental Procedures

A total of 41 Duroc barrows were used in 2 paired-feeding trials and a trio-feeding test (Experiments 1, 2 and 3) each of 6 weeks' duration to determine the practical optimum level of thiouracil to include in the ration of

[1] The data contained in this paper are from research by the senior author in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Animal Science.

[2] The authors gratefully acknowledge the donation of the thiouracil by the Lederle Laboratories, Pearl River, New York, through the courtesy of Dr. T. H. Jukes.

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fattening swine weighing 140 to 180 pounds initially and to compare the optimum level of thiouracil against the control ration under conditions of equalized feeding. Additional data on the latter comparison were obtained on 6 pairs of Duroc barrows fed the control ration and the 0.15 percent thiouracil ration in metabolism cages for 17–18 days (Experiment 7). A total of 30 fattening pigs was used in a group-feeding test (Experiment 4) and 12 Duroc barrows were used in an individual feeding test (Experiment 5), each of 6 weeks' duration, to determine the effect of 0.15 percent thiouracil on rate of gain, feed consumption and efficiency of gains of full-fed pigs. Seven pairs of barrows pair-fed to gain equally during a 28-day period in a carcass composition test (Experiment 6) furnished additional information on the effect of thiouracil on rate and efficiency of gains.

Pigs weighing 140 to 180 pounds initially were selected because it was expected that thiouracil would be most effective when fed after skeletal and muscular growth had slackened. It was hoped that the 42-day feeding period used in all tests except Experiments 6 and 7 would be slightly longer than the optimum length of time to feed thiouracil to fattening swine and thus show a fairly complete picture of the trends in feed comsumption, rate and efficiency of gains from week to week.

The control ration fed in Experiments 1 through 4 consisted of 76% ground yellow corn, 9.5% expeller soybean meal, 6% meat scraps (55% crude protein), 6% dehydrated alfalfa meal, 0.8% ground limestone, 0.8% steamed bone meal, 0.4% iodized salt, and 0.5% fortified vitamin A and D oil.[4] In experiments 5 through 7 the control ration consisted of 76% ground yellow corn, 10% expeller soybean meal, 6.5% meat scraps (55% crude protein), 6% dehydrated alfalfa meal, 0.5% ground limestone, 0.5% iodized salt, and 0.5% fortified vitamin A and D oil. One-eighth pound of manganese sulfate was added to each 1000 pounds of the above rations.

In Experiments 4 and 5, the data were treated statistically by applying the t-test for unpaired differences (Fisher, 1932). In all other experiments the data were treated statistically by applying the t-test for paired differences (Student, 1908).

Results and Discussion

Determining the Optimum Level of Thiouracil for Fattening Swine

A series of 3 paired-feeding tests, each of 6 weeks' duration was conducted with Duroc barrows to determine the optimum level of thiouracil to include in the ration of fattening barrows weighing 140 to 180 pounds initially.

(*a*) *Experiment 1 (0.1% vs. 0.2% thiouracil).* A summary of the results of Experiment 1 is presented in table 1. The 0.2% level of thiouracil promoted

[4] Guaranteed to contain 2000 I.U. of vitamin A and 400 I.U. of vitamin D per gram.

significantly more rapid and more efficient gains than 0.1% thiouracil.

(*b*) *Experiment 2 (0.15% vs. 0.25% thiouracil).* The results of Experiment 2 are briefly summarized in table 1. There was no difference in average daily gain between pigs fed 0.15% or 0.25% thiouracil in the ration. The pigs fed these levels of the drug made very rapid and efficient gains. From the standpoint of economy and of the lessened possibility of toxic effects, 0.15% thiouracil would appear to be more practical than 0.25% of the drug.

TABLE 1. SUMMARY OF 0.1% VS. 0.2%, 0.15% VS. 0.25%, AND 0.15% VS. 0.20% THIOURACIL FOR PIGS PAIR-FED EQUAL AMOUNTS OF FEED DAILY, EXPERIMENTS 1, 2, AND 3

Items compared	Exp. 1		Exp. 2		Exp. 3	
	(Level of thiouracil)					
	0.1%	0.2%	0.15%	0.25%	0.15%	0.20%
No. of pigs	6	6	6	6	6	6
Days on test	42	42	42	42	42	42
Av. initial wt., lb.	168	168	159	160	164	164
Av. final wt., lb.	220	225	232	232	229	225
Av. daily feed per pig, lb.	3.97	3.97	4.69	4.69	4.57	4.57
Av. daily gain, lb.	1.24	1.36*	1.73	1.73	1.55[1]	1.14
Av. feed per 100 lb. gain, lb.	320	292*	270	272	298	327

* $P \leqq 0.05$, significant

[1] $P \leqq 0.06$

(*c*) *Experiment 3 (control vs. 0.15% vs. 0.20% thiouracil).* In Experiment 3, the most effective level from Experiment 1 (0.2%) and the lower level from Experiment 2 (0.15%) were compared and checked against a control using the trio-feeding technique. A summary of the results obtained from the 6 pairs of barrows that were fed 0.15% and 0.20% thiouracil in this test is presented in table 1.

The difference in average daily gains of the pigs receiving 0.15% and 0.20% approached significance ($P \leqq 0.06$). Of the levels of thiouracil tested, 0.15% represented the most nearly optimum level to add to the control ration for fattening barrows weighing 140 to 180 pounds initially.

The Effect of 0.15% Thiouracil on Rate and Efficiency of Gains

The results reported in this section deal with a comparison of control and 0.15% thiouracil (optimum level in the first phase) under conditions of equalized feed intake, full-feeding and feeding for equalized gains.

(*a*) *Paired-feeding (equalized feed intake).* In the trio-feeding test (Experiment 3) one control pig was removed from experiment early in the test. A

summary of the results obtained from the 5 control barrows and their 5 pairmates that received 0.15% thiouracil in the trio-feeding test is presented in table 2 along with a similar comparison made in Experiment 7 with 6 pairs of barrows fed in metabolism cages for 17–18 days.

The results from Experiments 3 and 7 demonstrate conclusively that 0.15% thiouracil causes significant improvement in daily gains and in feed efficiency over controls when feed intake is equalized .

(*b*) *Full-feeding.* The object of Experiments 4 and 5 was to study the effect on rate and efficiency of gains of adding 0.15% thiouracil to a control ration under full-feeding conditions. This comparison was made in Experiment 4

TABLE 2. SUMMARY OF CONTROL VS. 0.15% THIOURACIL FOR BARROWS PAIR-FED EQUAL AMOUNTS OF FEED DAILY, EXPERIMENTS 3 AND 7

Items compared	Experiment 3		Experiment 7[1]	
	Control	0.15% Thiouracil	Control	0.15% Thiouracil
Number of pigs	5	5	6	6
Days on test	42	42	17.5	17.5
Average initial weight, lb.	166	166	142	142
Average final weight, lb.	207	234	162	169
Average daily feed per pig, lb.	4.80	4.80	3.77	3.77
Average daily gain, lb.	0.99	1.61**	1.16	1.60*
Average feed per 100 lb. gain, lb.	504	301**	328	239**

* $P \leq 0.05$, significant

** $P \leq 0.01$, highly significant

[1] Pigs fed in metabolism cages for 17–18 days for nitrogen balance studies. The latter studies are to be presented in a later manuscript.

with group-fed, self-fed pigs and in Experiment 5 with pigs hand-fed individually to the limit of appetite. The results of both tests are presented in table 3.

The results of Experiment 4 and 5 are in excellent agreement, and indicate that the thiouracil pigs (1) showed no significant increase in cumulative gains over controls, but gained significantly slower than controls during the fifth and sixth weeks, (2) consumed from 1.5 to 1.7 pounds less feed per pig daily than controls and (3) required 54 to 75 pounds (14% to 21%) less feed per 100 pounds of gain than controls during a test period of 3 to 6 weeks. Statistical analysis of the individual feed data in Experiment 5 showed that the addition of thiouracil to the ration very significantly reduced feed consumption as well as the feed required per unit of gain. Thus, under *ad libitum* or full-feeding conditions, the chief advantage of thiouracil-feeding is to improve the efficiency of gain, rather than to increase the rate

TABLE 3. SUMMARY OF CONTROL VS. 0.15% THIOURACIL UNDER FULL-FEEDING CONDITIONS, EXPERIMENTS 4 AND 5

Items compared	Experiment 4 Group-Fed		Experiment 5 Individually Fed	
	Control	0.15% Thiouracil	Control	0.15% Thiouracil
Number of pigs	15[1]	15[1]	6	6
Days on test	42	42	42	42
Average initial weight, lb.	170	170	166	166
Average final weight, lb.	243	241	236	229
Average daily feed per pig, lb.	8.08	6.60	6.11	4.42**
Average daily gain, lb.	1.73	1.68	1.65	1.50
Feed per 100 lb. gain, lb.	467	392	371	296**

** $P \leq 0.01$, highly significant

[1] Five Duroc barrows, 6 Chester White barrows, 1 Poland China barrow and 3 Duroc gilts in each lot.

of gain. After 4 weeks of thiouracil-feeding, gains and feed consumption decreased quite rapidly but feed efficiency remained high. Four weeks appeared to be the optimum length of time to feed the drug.

(c) *Paired feeding for equalized gains.* Seven pairs of barrows were pair-fed for equal gains during a 4-week period for a carcass composition test (Experiment 6). The feed and gain data procured in this test are useful in helping

TABLE 4. SUMMARY OF CONTROL VS. 0.15% THIOURACIL FOR BARROWS[1] PAIR-FED FOR EQUAL GAINS, EXPERIMENT 6

Items compared	Control	0.15% Thiouracil
Number of pigs	7	7
Days on test[2]	26	28
Average initial weight, lb.	175.6	175.4
Average final weight, lb.	224.1	225.3
Average daily feed per pig, lb.	6.04	5.37**
Average daily gain, lb.	1.75	1.80*
Average feed per 100 lb. gain, lb.	346	301**

* $P \leq 0.05$, significant

** $P \leq 0.01$, highly significant

[1] Four pairs of Duroc barrows and 3 pairs of Chester White barrows were used.

[2] One pair was on test only 26 days.

to explain the effect of 0.15% thiouracil on rate and efficiency of gains. A brief summary of Experiment 6 is presented in Table 4. The carcass composition results of this test are to be reported in a later manuscript.

The differences in average daily gain between the controls and the thiouracil barrows was only 0.05 pound and the difference in average weight

of the two groups at the end of the test was only 1.2 pounds. In this test a very small and consistent difference favoring the thiouracil barrows was statistically significant. The barrows receiving 0.15% thiouracil required significantly less feed per unit of gain. The 0.15% thiouracil ration was 1.15 times as effective in promoting gains as the control ration under the conditions of this test.

Summary and Conclusions

Using the paired-feeding, trio-feeding, group-feeding and individual-feeding techniques, 109 fattening swine were fed to determine the practical optimum level of thiouracil to include in the ration and the effect of this level on rate and efficiency of gains.

Within the limits of the conditions covered in the study, the following conclusions appear justified.

1. Of the levels of thiouracil tested (0.1%, 0.15%, 0.20%, and 0.25%), 0.15% represents the most nearly optimum level to add to an adequate ration for fattening barrows weighing 140 to 180 pounds initially. For the remaining purposes of this study, this level of the drug was used.

2. Under conditions of equalized feed intake, thiouracil increases the rate of gain of pigs significantly and reduces the amount of feed consumed per unit of gain significantly.

3. When comparable pigs are fed to the limit of appetite either individually or in groups, adding thiouracil to an adequate ration does not increase the rate of gain but it does significantly reduce the amount of feed required per unit of gain as well as the feed consumption. Thus, the chief benefit from thiouracil under conditions of full-feeding is the increase in efficiency of gains rather than any increase in rapidity of gains.

4. When rations are fed to produce equal rates of gain, adding thiouracil to an adequate ration reduces significantly the amount of feed required.

5. The optimum length of time to feed thiouracil is about 4 weeks, since thiouracil significantly reduces feed consumption and daily gains of full-fed pigs after 4 weeks of feeding. However, advantage can be taken of the feed-saving feature of the drug for 6 weeks with little loss in over-all gains.

6. The power of thiouracil to increase rate of gain exerts its greatest effect during either the second or third week of feeding.

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THE EFFECT OF THYROPROTEIN AND THIOURACIL ON THE GROWTH AND FATTENING OF SWINE[1]

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THE influence of the thyroid gland on metamorphosis, growth, general cellular metabolism and numerous other body functions is well known. In recent years numerous attempts have been made to alter normal patterns of reproduction, growth, fattening and milk and egg production by the experimental production of hypo- and hyperthyroidism.

The effects of hyperthyroidism induced by thyroprotein or hypothyroidism produced by the various goitrogens have been studied by numerous investigators. Although there appears to be some disagreement of results, many of the differences may perhaps be explainable as species, age, sex and environmental differences.

Beeson *et al.* (1947), and Perry *et al.* (1948) reported increased gain and feed efficiency with Durocs. Reineke, McMillen *et al.* (1947, 1948) reported increased gain and feed efficiency in Duroc, Berkshire and Yorkshire pigs but less response in Chester White hogs. Vander Noot *et al.* (1948) found that thyroprotein had little effect on growth at levels up to 0.225 gm. per 100 lb. body weight per day and that higher dosages reduced growth. However, thyroprotein feeding was discontinued when the pigs weighed 125 pounds. Braude (1947) was unable to improve the growth of swine with thyroprotein and at higher dosages the rate of gain was reduced.

Goitrogen-induced hypothyroidism has consistently improved the fattening and carcass quality of chickens (Kempster and Turner, 1945, Andrews *et al.* (1946, 1947) and increased the caloric feed efficiency. Although not always statistically significant, the goitrogens have consistently reduced the rate of growth in chickens. Andrews *et. al.* (1947) found that thiouracil slightly reduced the rate of gain in fattening lambs and there was some indication that fattening might have been increased slightly. In cattle (Beeson *et. al.*, 1947) thiouracil appeared to have little effect at levels up to 6 gm. per steer per day. Muhrer and Hogan (1945) reported that in paired feeding experiments, thiouracil-fed pigs gained faster and more efficiently than control pigs fed the same amount of feed, but the gains were much less than in full fed normal pigs. McMillen *et. al.* (1947) concluded

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that thiouracil reduced the rate of gain but that the efficiency of gain is increased. Terrill (1948) found that the optimum content of thiouracil in the ration of fattening hogs is 0.15 percent, that the optimum time to use thiouracil is the last four weeks of the fattening period and that the chief benefits under full feeding conditions was to increase the efficiency of gains. Thiouracil partially inhibited skeletal growth and reduced dressing percentage about one percent.

A review of the literature indicates that growth rate and carcass type in young animals is affected by the thyroid activity of the animal. If possible it would be desirable to alter the activity of the thyroid gland in such a manner that a maximum growth rate at a reasonable feed efficiency be obtained. Also, it would be desirable to modify carcass type and to alter the ratio of lean to fat in the carcass. The objectives of these trials, therefore, were to study the effect of altering thyroid activity on (1) growth rate, (2) feed efficiency, and (3) carcass characteristics.

Materials and Methods

In three trials reported here, purebred Duroc hogs were fed a basal ration which had the following composition: ground yellow corn, 66 percent; groung wheat, 20 percent; Purdue Supplement V,[3] 13 percent; and minerals,[4] 1 percent.

In the first trial conducted during the winter of 1946–47, 24 weanling pigs were divided into four lots in which one served as the control and received only the basal ration while the other three received, in addition to the basal ration, 0.1 percent thiouracil, 0.0044 percent thyroprotein (2 gm. per 100 lb. feed) and 0.0088 percent thyroprotein (4 gm. per 100 lb. feed) respectively.

In the second trial conducted during the summer of 1947, 64 weanling Duroc pigs were divided into eight lots in which duplicate pens received the following treatments: (I) the basal ration; (II) the basal ration plus 0.0088 percent thyroprotein until the animals averaged 150 pounds live weight, then the feeding of the thyroprotein was discontinued and the feeding of 0.1 percent thiouracil was started; (III) the basal ration plus 0.0088 and (IV) 0.0132 per cent thyroprotein, respectively.

In the third trial conducted during the winter of 1947–48, 32 weanling Duroc pigs were divided into four groups in which the control group received the basal ration and the other three groups received, in addition to the basal ration, 0.0088, 0.0132, and 0.0176 percent thyroprotein, respectively.

[3] Purdue Supplement V consists of soybean oil meal, 40; fish meal, 20; meat scraps, 20; alfalfa meal, 10; and cotton seed meal, 10 pounds.

[4] Mineral mixture consists of equal parts of ground limestone, steamed bone meal, and salt.

Results and Discussion

The Effects of Thiouracil on Weanling Pigs—(Trial I).

At the time this experiment was planned (1946) the marked growth-depressing effects of thiouracil on pigs were not known. The pigs which received 0.1 percent thiouracil beginning at 53 pounds (table 1) made greater and more efficient gains than any other group during the first two weeks of

TABLE 1. THE EFFECT OF THYROPROTEIN AND THIOURACIL ON THE GROWTH, FEED CONSUMPTION AND FEED EFFICIENCY OF WEANLING PIGS

Trial I., Winter 1946–47. Fed 84 days

Treatment	No. of pigs	Ave. initial weight, lb.	Ave. final weight, lb.	Ave. total gain, lb.	Ave. daily gain, lb.	Daily feed, lb.	Feed consumed per 100 lb. gain, lb.	Thyroprotein per day per 100 lb. live weight, gm.
Control	6	53	196	143	1.71	7.2	420	—
0.1% Thiouracil[1]	6	53	143	90	1.06	4.1	388	—
0.0044% Thyroprotein	6	54	194	140	1.67	6.7	400	.113
0.0088% Thyroprotein	6	54	222	168[2]	2.01	7.6	378	.242

[1] Thiouracil feeding was stopped after six weeks on trial.

[2] Least significant difference for gain in weight is 20.3 pounds at the 5 per cent level.

the experiment. By the end of the third week the rate of growth was subnormal, feed intake had been reduced by the fourth week and the pigs had locomotive and respiratory disturbances. After five weeks of thiouracil treatment three of the six pigs developed severe myxedema (figure 1) and at six weeks it became evident that the correction of the severe hypothyroidism was necessary for the continuance of growth and perhaps for survival. When the diet was changed to the basal ration plus 0.0088 percent thyroprotein the symptoms of myxedema began to disappear by the end of the first week and after three weeks the clinical evidence of hypothyroidism was no longer recognizable.

The Effects of Thiouracil Following Thyroprotein Treatment—(Trial II).

It was hypothesized that if skeletal and muscle growth were first stimulated by thyroprotein-induced hyperthyroidism then it might be possible

subsequently to regulate fat deposition by the use of thiouracil. The growth rate of pigs which received a ration containing 0.0088 percent thyroprotein from weaning until 150 lb. was similar to that of the controls. When this ration was changed to one containing 0.1 percent thiouracil growth practically ceased for two weeks and then was resumed at the same rate as the

Figure 1. Effects of feeding 0.1 percent thiouracil to weanling pigs. A severe case of myxedema, showing thickening and cracking of skin.

controls. This can be explained in terms of our present knowledge by the fact that during thyroprotein administration the animal's thyroid gland is relatively quiescent. It would appear that the use of thiouracil in animals with already subnormal thyroids produced a degree of hypothyroidism which inhibited growth. The resumption of growth after two weeks is pre-

sumably due to the increased activity of the thyroid gland, even though thiouracil was being administered (table 2).

Influence of Thyroprotein on Growth, Feed Consumption and Feed Efficiency.

Because of the seasonal differences in thyroid activity and differences in the growth of swine at different environmental temperatures it was decided to conduct both winter and summer experiments. No attempt was made to alter the environmental temperature, humidity or air movement.

TABLE 2. THE EFFECT OF THYROPROTEIN AND THIOURACIL ON THE GROWTH, FEED CONSUMPTION AND FEED EFFICIENCY OF WEANLING PIGS

Trial II, Summer 1947. Fed 104 days

Treatment	No. of pigs	Ave. initial weight, lb.	Ave. final weight, lb.	Ave. total gain, lb.	Ave. daily gain, lb	Daily feed, lb. lb.	Feed consumed per 100 lb. gain, lb.	Thyroprotein per day per 100 lb. live weight, gm.
Control	16	41	221	180	1.72	6.3	367	—
Thyroprotein[1] then Thiouracil	15	42	216	174	1.67	6.1	364	—
0.0088% Thyroprotein	14	41	230	189	1.77	6.5	366	.206
0.0132% Thyroprotein	14	41	235	194[2]	1.80	6.6	369	.314

[1] 0.0088 percent thyroprotein was fed until the animals weighed 150 pounds, then 0.1 percent thiouracil was fed.
[2] Least significant difference for gain in weight is 14 pounds at the 5 percent level.

Trial I—(*Winter*—1946–47). As summarized in table 1 the addition of thyroprotein to the basal ration at a level of 0.0044 percent had no effect on rate of growth. The rate of gain was significantly increased, however, ($P < 0.05$) when the ration contained 0.0088 percent thyroprotein. Both groups receiving thyroprotein required less feed per 100 lb. of gain than did the controls (table 1).

Trial II—(*Summer*—1947). The feeding of thyroprotein at the level of 0.0132 percent resulted in significantly increased growth rate ($P < 0.05$) as this group gained 194 pounds in 104 days while the controls gained 180 pounds (table 2). Although not significantly different, the group receiving thyroprotein at the level of 0.0088 percent gained nine pounds more than the control group. This followed the general trend of increased growth from

the feeding of thyroprotein. In this trial there was no appreciable difference between lots in the amount of feed required per unit of gain, but the feed intake was increased slightly by thyroprotein feeding.

Trial III—(Winter—1947–48). The feeding of thyroprotein in this trial resulted in increased growth rate of from 10 to 27 pounds according to the level at which the thyroprotein was fed. However, only the gain made by the group receiving thyroprotein at the level of 0.0176 percent (188 pounds)

TABLE 3. THE EFFECT OF THYROPROTEIN OF GROWTH, FEED CONSUMPTION AND FEED EFFICIENCY OF WEANLING PIGS

Trial III, Winter 1947–48. Fed 95 days

Treatment	No. of pigs	Ave. initial weight, lb.	Ave. final weight, lb.	Ave. total gain, lb.	Ave. daily gain, lb.	Daily feed, lb.	Feed consumed per 100 lb. gain, lb.	Thyroprotein per day per 100 lb. live weight, gm.
Control	8	40	201	161	1.70	7.0	417	—
0.0088% Thyroprotein	7	40	211	171	1.77	6.7	378	.215
0.0132% Thyroprotein	8	40	218	178	1.88	7.4	396	.361
0.0176% Thyroprotein	8	80	228	188[1]	1.98	8.2	412	.530

[1] Least significant difference for gain in weight is 18.6 pounds at the 5 percent level.

was significantly greater ($P < 0.05$) than that made by the control group (161 pounds).

All groups receiving thyroprotein required less feed per unit gain than the control group although the groups receiving thyroprotein at the higher levels were less efficient than those receiving thyroprotein at the lower levels.

In nearly all cases the feeding of thyroprotein increased the daily feed consumption of the pigs (table 3) and this was especially noticeable for the pigs receiving 0.0176 percent thyroprotein.

Influence of Various Levels of Thyroprotein on Carcass Measurements

In the first two trials, all animals were marketed at the time the fastest gaining group weighed approximately 225 pounds. After the animals were

slaughtered, standard carcass measurements, as outlined by the Association of Official Agricultural Chemists (sixth edition, 1945) were taken. At the end of the third trial, those animals weighing over 215 pounds were selected from each lot and, after being slaughtered, carcass measurements were taken. The remaining animals were continued on their respective rations until they

TABLE 4. THE EFFECTS OF THYROPROTEIN AND THIOURACIL ON CARCASS MEASUREMENTS

	Carcass weight, lb.	Carcass length, in.	Leg length, in.	Chest depth with fat, in.	Chest depth, lean only, in.	Back fat at 7th dorsum, mm.	Back fat at 4th lumbar, mm.
			TRIAL I (Winter—1946–47)				
Control	138	27.6	19.5	15.0	11.6	51	59
0.0044% Thyroprotein	136	28.0	19.6	14.8	11.3	51	54
0.0088% Thyroprotein	156	28.8[1]	19.6	15.2	11.7	53	58
			TRIAL II (Summer—1947)				
Control	147	29.4	20.3	15.4	12.2	50	44
Thyroprotein,[2] then Thiouracil	145	28.8	20.2	15.2	12.0	48	43
0.0088% Thyroprotein	154	29.9	20.9	15.5	12.4	47	47
0.0132% Thyroprotein	156	30.3[3]	20.7	15.5	12.0	46	45
			TRIAL III (Winter—1947–48)				
Control	152	29.2	20.5	14.3	10.5	45	46
0.0088% Thyroprotein	156	30.1	21.1	14.6	10.9	44	43
0.0132% Thyroprotein	158	29.9	20.8	14.6	10.8	48	49
0.0176% Thyroprotein	154	29.6	20.5	14.8	11.8[4]	46	47

[1] The least significant difference for carcass length is 1.1 inches at the 5 percent level.
[2] 0.0088 percent thyroprotein was fed until the animals averaged 150 pounds, then 0.1 percent thiouracil was fed.
[3] The least significant difference for carcass length is 0.9 inches at the 5 percent level.
[4] The least significant difference for chest depth (lean only) is 1.3 inches at the 1 percent level.

more nearly averaged 225 pounds live weight, then they were slaughtered. It was thought more comparable data might be obtained in this manner.

Trial I—(*Winter*—1946–47). When thyroprotein was fed at the level of 0.0088 percent, carcasses were produced which were significantly longer ($P < 0.05$) than those of the control group. However, the difference was probably due to the greater live weight of hogs at the same age. There was no significant difference in other standard carcass measurements such as chest depth or depth of back fat (table 4).

Trial II—(*Summer*—1947). The feeding of thyroprotein at the level of 0.0132 percent resulted in animals whose carcasses were significantly longer ($P < 0.05$) than those from the control groups, but once again this may be attributed to the greater live weight of the thyroprotein-fed animals of the same age.

Trial III—(*Winter*—1947–48). Significantly greater ($P < 0.01$) chest depth (lean only) was obtained by the feeding of thyroprotein at the level of 0.0176 percent. Although there was a general trend toward carcass measurements of greater magnitude in the case of animals which received thyroprotein, there was no other significant difference in carcass measurements between any of the groups.

Discussion

Thyroid function may be influenced by species, age, sex and environmental differences and it would be unusual to find complete agreement among the results of the various investigators. The influence of thiouracil on growth rate was essentially the same as has been reported by others in swine (McMillen *et al.*, 1947) in chickens (Andrews *et al.*, 1947) and in rats (Astwood *et al.*, 1943). As previously reported by others, both swine and sheep consume less feed when thiouracil is administered (McMillen, *et al*, 1947), (Muhrer *et al.*, 1947), (Andrews *et al.*, 1947).

McMillen, Reineke *et al.* (1947, 1948) have reported rather consistent increases in growth of thyroprotein fed Duroc, Berkshire and Yorkshire swine but not Chester White. Although there have been some differences between trials, the Duroc hogs used in these experiments have gained at increased rates when thyroprotein was fed. This has been especially true when levels of 0.0176 and 0.0132 per cent thyroprotein were used. Vander Noot *et al.* (1948) concluded that thyroprotein had no beneficial effects on growth rate at levels of up to 0.225 gm. per 100 lb. body weight and that at higher dosages growth was inhibited. As previously pointed out, their experiments were terminated when the hogs weighed about 135 lb. Had the Purdue studies been concluded at the corresponding period the conclusions would have been similar. The differences in growth rate were most marked in the period between 150 and 225 lb.

In table 4 it may be observed in the carcass measurements for Trials I and II that the animals receiving thyroprotein produced longer carcasses at the same age. However, in observing the results for Trial III it can be seen there was very little difference in this measurement when the thyroprotein-fed pigs were compared with the controls at approximately the same carcass weight. In other words, the difference between the carcass measurements of the control group and of the thyroprotein groups in Trials I and II was due the fact that the thyroprotein groups grew faster and attained greater dimensions at an earlier age.

Although the feeding of thiouracil did not alter the carcass quality of animals reported in these trials, other workers have reported fatter carcasses from animals that received thiouracil. Muhrer and Hogan (1945) and Zorn and Brugermann (1939) found that hogs which received thiouracil produced carcasses higher in fat content than hogs on the basal ration. Andrews *et al.* (1947) produced lamb carcasses of higher market grade by the feeding of thiouracil.

Summary

A thiouracil intake of 0.1 percent of the ration resulted in highly significantly reduced growth rate, reduced food intake, and caused severe myxedema in weanling pigs.

When thiouracil was fed at the level of 0.1 percent of the ration to pigs which averaged 150 pounds live weight and which previously had received thyroprotein at the level of 0.0088 percent of the ration, growth was almost stopped and it was not until after two weeks that the animals began to grow at about the same rate as the animals in the control groups.

Significantly increased growth rate was obtained by the feeding of thyroprotein at the level of 0.0088 percent of the ration in Trial I, at the level of 0.0132 percent of the ration in Trial II, and at the level of 0.0176 percent of the ration in Trial III. The feeding of thyroprotein at all levels caused an increased growth rate.

Less feed per unit of gain was required by animals receiving thyroprotein in Trials I and III. In Trial II, animals receiving thyroprotein required no more feed per unit of gain than the control animals.

When carcass comparisons were made on animals that were of approximately the same weight at the time of slaughter, (Trial III) carcasses from animals which received thyroprotein at the level of 0.0176 percent had highly significantly greater chest depth (lean only) than the control group.

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THE EFFECT OF LIBERAL B-VITAMIN SUPPLEMENTATION ON GROWTH OF WEANLING PIGS FED RATIONS CONTAINING A VARIETY OF FEEDSTUFFS[1]

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IT is well known that a ration composed of yellow corn, tankage, soybean meal, alfalfa meal and minerals is inadequate for optimum growth and lactation performance when fed to swine in dry-lot. Results of many trials especially at the Illinois, Missouri and Wisconsin Stations, prove that not only do such rations fail to promote optimum growth and lactation but various abnormalities appear in the pigs. Keith, Miller, Thorp and McCarty (1942) observed deficiency symptoms in large growing pigs on this type of ration. Much of the earlier work along this line is reviewed by Fairbanks, Krider and Carroll (1944) and Krider, Fairbanks and Carroll (1944). Krider and co-workers found that alfalfa meal and distillers solubles brought about nutritional improvement, but the weaning weights of the pigs and subsequent gains were below normal. Pigs from litters fed alfalfa and distillers solubles as well as the pigs fed the basal diets developed diarrhea, dermatitis and various leg abnormalities. Results of these studies led the authors to suggest that the growing-fattening pig may require more of the known vitamins than the literature indicates.

Luecke, McMillen, Thorp and Tull (1947, 1948) found that the nicotinic acid requirement of pigs fed rations of natural feedstuffs are much higher than the early requirements established on a synthetic diet. The results of Powick, Ellis, Madsen and Dale (1947a, 1947b) also indicate a high requirement for nicotinic acid. McMillen, Luecke and Thorp (1948) and Luecke, Thorp, McMillen and Dunne (1949) found that rations composed of natural feedstuffs may not supply adequate amounts of pantothenic acid.

Krider *et al.* (1948) and Luecke *et al.* (1947, 1948) have shown that weanling pigs exhibit a marked response in growth and efficiency to B-vitamin supplementation when fed a corn-soybean ration in dry-lot.

Dyer, Krider and Carroll (1948) presented evidence to show that supplementation with niacin, pantothenic acid and riboflavin was as effective as

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the addition of several other B-vitamins to a corn-soybean ration. The purpose of this paper is to present results of two trials in which B-vitamin supplements were added to rations consisting of a variety of feedstuffs for small weanling pigs on concrete floors.

Experimental

The trials were conducted during the fall and winter of 1948–49. In trial A, purebred Duroc Jersey pigs that were raised on concrete floors were used. The dams received a 16 percent total crude protein mixture of the same feeds used in the trial (see table 1) and the pigs had access to this 16 percent protein mixture in a creep before weaning. The pigs were seven weeks old when placed on experiment.

TABLE 1. COMPOSITION OF BASAL RATIONS

Ingredients[1]	Ration	
	A	B
Ground yellow corn	48	68
Oats	15	—
Soybean oil meal (expeller)	12	12
Meat scraps	12	12
Alfalfa meal[2]	10	5
Complex mineral mixture	3	3
Composition:		
Crude protein	19.50	18.20
Thiamine, mg. per lb. of feed	1.50	1.30
Riboflavin, mg. per lb. of feed	1.12	0.97
Pantothenic acid, mg. per lb. of feed	5.04	4.35
Nicotinic acid, mg. per lb. of feed	12.15	13.50

[1] When synthetic vitamins were added to both rations they were added in the following amounts per pound of feed: nicotinic acid, 25 mg.; calcium pantothenate, 15 mg.; riboflavin, 5 mg.; thiamine, 5 mg.; pyridoxine, 2 mg.; B_{12} concentrate (Merck,) 0.25%; and choline chloride, 0.1%.

[2] The alfalfa meal in ration A was dehydrated 17% protein and in ration B was sun-cured 15% protein.

In trial B, pasture raised Duroc×Poland×Hampshire pigs were used. They were self-fed a 16 percent protein feed mixture with their mothers and averaged about seven weeks of age at the start of the trial. In both trials the concrete pens were bedded with shavings. A constant supply of water was available for the pigs and the rations were self-fed.

The pigs were fed the feed mixtures shown in table 1 with B-vitamin supplements fed to the lots as shown in tables 2 and 3. The crude protein and B-vitamin analyses of the two rations used in the experiment are shown in table 1. Riboflavin, pantothenic acid and nicotinic acid were determined

microbiologically, and thiamine was determined chemically by the thiochrome method.

TABLE 2. INFLUENCE OF B-VITAMIN SUPPLEMENTS ON GAINS AND FEED REQUIREMENTS
TRIAL A
(Seven pigs in each lot, trial lasting ten weeks)

Lot No.	Ration	Initial weight lbs.	Av. daily gain lbs.	Av. daily ration lbs.	Feed per lb. of gain lbs.
1	Basal	24	.63	2.53	4.01
2	Basal+P.A.	24	.63	2.91	4.62
3	Basal+P.A.+Ribo.	24	.73	2.43	3.33
4	Basal+P.A.+Ribo.+N.A.	23	1.00*	3.14	3.14
5	Basal+P.A.+Ribo.+N.A.+Pyridoxine +Thiamine+Choline	24	.94*	3.06	3.26

* Daily gains highly significant over lot 1 ($P \leqq 0.01$).

TABLE 3. INFLUENCE OF B-VITAMIN SUPPLEMENTS ON GAINS AND FEED REQUIREMENTS
TRIAL B
(Eight pigs in each lot, trial lasting nine weeks)

Lot No.	Ration	Initial weight lbs.	Av. daily gain lbs.	Av. daily ration lbs.	Feed per lb. of gain lbs.
1	Basal	27	0.66	2.83	4.30
2	Basal+P.A.	26	0.68	2.88	4.23
3	Basal+N.A.	26	0.70	2.85	4.07
4	Basal+P.A.+N.A.	26	0.79	3.17	4.02
5	Basal+P.A.+N.A.+Ribo.	27	1.01*	3.26	3.23
6	Basal+P.A.+N.A.+Ribo.+B_{12}	27	1.02*	3.65	3.58
7	Basal+P.A.+N.A.+Ribo.+B_{12}+Thiamine+Pyridoxine+Choline	26	0.96*	3.27	3.41

* Daily gains significant over lot 1 ($P = 0.05$).

The amounts of B-vitamins added are given in a footnote to table 1. The complex mineral mixture was similar to the one reported by Luecke *et al.* (1947). Vitamins A and D were added to both rations in amounts which supplied 1500 I. U. of vitamin A and 150 I. U. of vitamin D per pound of feed.

Results and Discussion

Trial A

The results of B-vitamin supplementation in trial A are shown in table 2. Pigs in lot 1 on the basal ration gained only 0.63 pound per day and required 4.01 pounds of feed per pound of gain. There was no additional growth response in lot 2 from the addition of calcium pantothenate. In lot 3, the riboflavin supplement in addition to calcium pantothenate brought about an increase in the daily gain to 0.73 pound and decreased the feed required per pound of gain. During the fifth and sixth weeks several pigs in lot 3 exhibited diarrhea which may have been due to a borderline niacin deficiency. Two of the pigs showed typical niacin deficiency symptoms described by Dunne *et al.* (1949).

The pigs in lot 4 receiving supplementary calcium pantothenate, riboflavin and nicotinic acid made significantly higher daily gains (1.00 lb.) and required 22 percent less feed per unit of gain than the controls. The lot 5 pigs getting the six B-vitamins made an average daily gain of 0.94 pound. This gain is also significantly higher than the controls and not significantly different from the gains made by lot 4. Their gains were 19 percent more efficient than the control pigs in lot 1.

Trial B

The results in trial B are presented in table 3. There are no significant differences between the daily gains and feed requirements of lots 1, 2, 3 and 4. It is interesting that again as in trial A the addition of supplementary calcium pantothenate, nicotinic acid and riboflavin (lot 5) brought about a significant increase in daily gain. The lot 5 pigs made an average daily gain of 1.01 pounds daily and required 25 percent less feed than the lot 1 pigs fed the unsupplemented basal ration. The addition of vitamin B_{12} concentrate in lot 6 had no significant effect on gains or feed requirement. Again as in trial A, the addition of thiamine, pyridoxine and choline failed to further stimulate growth or increase feed efficiency. In fact, in both these trials the gains were slightly lower and the feed requirements higher when thiamine, pyridoxine and choline were added.

The lot 1 pigs getting only the basal ration in both trials exhibited diarrhea at various times during the experiments. Their hair coats were rough and they were obviously deficient. Four of the pigs in lot 1, trial B, were goose-stepping at the end of the trial.

These results indicate that the rations used were deficient in niacin, pantothenic acid and riboflavin. The levels of riboflavin, nicotinic acid and pantothenic acid in rations A and B (table 1) should be adequate for normal growth

when based on the recommendations of the National Research Council (1944). However, it appears that requirements for these vitamins on this type of feed mixture are considerably higher than those established from earlier experiments using synthetic diets.

Summary and Conclusions

Weanling 24-pound pigs were self-fed a basal ration of corn, oats, expeller soybean meal, meat scraps, alfalfa meal and complex mineral mixture on concrete floors.

Calcium pantothenate, riboflavin and nicotinic acid when added to the basal ration brought about a significant increase in daily gains, prevented the occurrence of deficiency symptoms, and reduced the feed required per unit of gain 22 to 25 percent.

In two trials supplements of thiamine, pyridoxine and choline failed to further increase gains or lower the feed requirement. In one trial, vitamin B_{12} concentrate also failed to increase gains and efficiency above the increase due to the supplement of pantothenic acid, nicotinic acid and riboflavin.

It is concluded that the rations used were deficient in pantothenic acid, nicotinic acid and riboflavin under the conditions of these trials and that liberal supplementation of these vitamins overcame the deficiency.

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THE AMINO ACID REQUIREMENTS OF SWINE, LYSINE[1]

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IT has been known for many years that the lysine content of corn is low. Since corn constitutes about 60 percent of all swine rations, the investigation as to the effect of lysine on the growth of weanling pigs seems to be of practical as well as of fundamental importance. In addition to lysine, corn is deficient in the amino acid, tryptophan. Beeson, Mertz and Shelton (1948) have shown that tryptophan is indispensable for the growing pig. In this experiment, growth for a period of 5 to 6 weeks was used as the criterion to prove the essential nature of this amino acid.

In the classical experiments of Osborne and Mendel (1914), lysine was proved to be essential for growth in the young white rat. Rose (1938) fed a diet containing a mixture of purified amino acids to young white rats and found that the best growth rate was obtained when the diet contained not less than 1.0% L-lysine.

Almquist and Mecchi (1942) using diets containing casein, zein and edestin found that the best growth rate was obtained in chicks when the diet contained not less than 0.9% L-lysine. In addition, lysine has been proved essential for the adult dog (Rose and Rice, 1939), young mouse (Bauer and Berg, 1943) and adult young men (Rose, 1947).

Studies which show the detrimental effects of a lysine-deficient (zein) diet on growth rate, feed consumption and feed efficiency of weanling pigs are presented.

Experimental Procedure

Since zein is devoid of lysine (Block and Bolling, 1945), it can be used as the sole source of protein in a lysine-deficient purified ration. Zein is also low in tryptophan, glycine and histidine. Therefore, by supplementing with these amino acids it is possible to formulate a more balanced amino acid mixture which is deficient in lysine.

The basal ration is shown in table 1. It contained 23.5% protein and 0.02% lysine,[3] and was fed to the pigs in group B. Two percent DL-ly-

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[3] Determined in this laboratory by microbiological assay.

TABLE 1. COMPOSITION OF BASAL RATION

Component	%	Vitamin Supplements	Mg. daily per kg. live wt.
Zein	26.1	1. Water-soluble vitamins	
Dextrose	29.5	Thiamin hydrochloride	0.40
Dextrin	25.0	Riboflavin	0.12
Lard	11.0	Nicotinic acid	1.20
Mineral mixture[1]	5.2	Pyridoxine hydrochloride	0.20
Celluflour	2.0	Calcium pantothenate	0.50
Liver extract	0.5	Choline chloride	10.00
DL-tryptophan	0.4		
Glycine	0.13		Levels daily per pig
L-histidine · HCl	0.17		
	100.00	2. Fat-soluble vitamins	
		Vitamin A[2]	3000 I.U.
		Vitamin D[2]	400 I.U.
		Alpha tocopherol	50 mg.
		Menadione	2 mg.

[1] Heinemann *et al.* (1946).
[2] Fed as Nopco XX.

TABLE 2. EFFECT OF LYSINE ON GROWTH RATE, FEED CONSUMPTION AND FEED EFFICIENCY

	Group A							
	First 28-day period (Basal+Lysine)				Total 42-day period (Basal+Lysine)			
Pig Number	1	3	5	7	1	3	5	7
Sex	M	F	M	F	M	F	M	F
Initial weight (lb.)	37.0	35.5	35.0	37.0	37.0	35.5	35.0	37.0
Final weight (lb.)	62.0	52.5	56.0	68.5	79.5	62.5	71.5	84.0
Daily gain (lb.)	0.89	0.61	0.75	1.12	1.01	0.64	0.87	1.12
Daily feed consumption (lb.)	3.55	3.21	3.34	3.54	3.88	3.46	3.64	3.89
Feed per pound of gain (lb.)	3.98	5.28	4.45	3.14	3.84	5.40	4.18	3.47
	Group B							
	First 28-day period (Basal only)				Second 28-day period (Basal+Lysine)			
Pig Number	2	4	6	8	2	4	6	8
Sex	M	F	M	F	M	F	M	F
Initial weight (lb.)	35.5	35.5	34.5	31.5	33.5	35.5	34.0	33.5
Final weight (lb.)	33.5	35.5	34.0	33.5	51.5	53.5	61.0	57.0
Daily gain (lb.)	−0.07	0.00	−0.02	+0.07	0.64	0.64	0.96	0.84
Daily feed consumption (lb.)	2.21	2.19	2.35	2.01	2.92	2.50	3.56	3.23
Feed per pound of gain (lb.)	—	—	—	—	4.56	3.91	3.71	3.85

sine·HCL was added to the basal ration to provide the diet for the control animals (group A). Lysine was added at the expense of an equivalent weight of dextrose. This was the only difference in the two diets.

Litter mates consisting of four male and four female purebred Duroc weanling pigs weighing about 35 pounds were paired for this experiment. Prior to weaning, these pigs had access to a balanced natural diet plus rye pasture. The animals were placed in individual pens equipped with raised wire screen

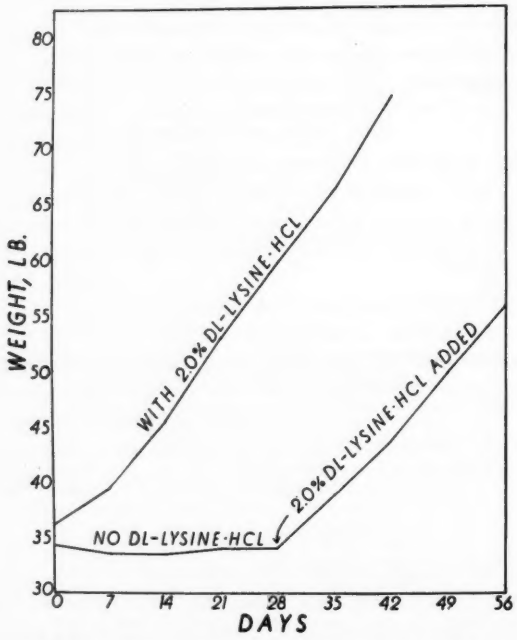

Figure 1. The effect of lysine on the growth of pigs.

floors and were fed twice daily in amounts to satisfy the individual appetite of each animal. The animals in group A were carried on the control diet for 42 days, whereas the animals in group B were carried on the basal ration (lysine-deficient) for 28 days. Since the effects of the lysine deficiency were apparent at the end of this time, the animals were fed the control ration (basal+lysine) to prove whether or not the deficiency could be corrected by the addition of lysine.

Results and Discussion

The results of the effect of lysine on growth rate, feed consumption, and feed efficiency are summarized in table 2. Group A (basal+2.0% DL-lysine·HCl) continued to maintain a good rate of gain throughout the 42-day period. During this period they made an average daily gain of 0.91 pound per day and consumed an average of 3.72 pounds of feed per pig daily.

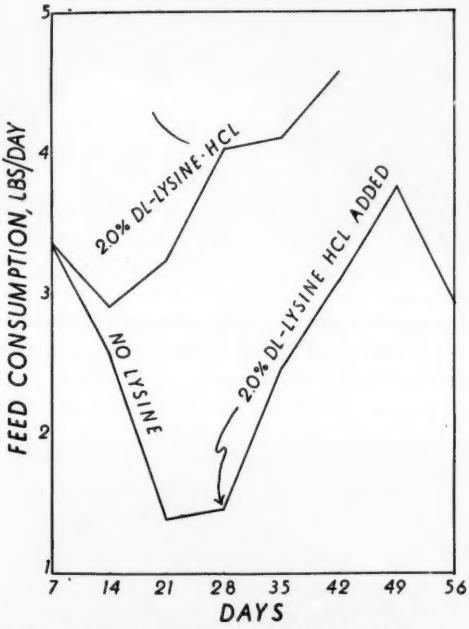

Figure 2. The effect of lysine on feed consumption. The decline in consumption the last week (see lower curve) is attributed to extremely hot weather.

Figures 1 and 2 show that the growth rate and feed consumption remained at a high level throughout the experiment for the pigs on the control ration. In addition, no signs of ill health or unthriftiness were observed in any of this group (see figure 3).

Group B pigs (lysine-deficient), on the other hand, were unable to gain weight. Figure 1 shows that these animals just maintained their starting weights over a 28-day period. Figure 2 shows that the feed consumption in group B was the same as in group A at the end of the first 7 days, and 90% of the value for group A at the end of the first 14 days. Feed consumption

Figure 3. Pig No. 1 (basal +2.0% DL-lysine·HCl) gained 25.0 pounds in 28 days.

Figure 4. Lysine-deficient pig No. 2 (basal diet only) lost 2.0 pounds in 28 days.

remained high in the control animals but dropped markedly after the fourteenth day in the lysine-deficient pigs, reaching a minimum value on the twenty-first day. During the first 28 days the average daily feed consumption of the group B pigs (lysine-deficient) was 2.19 pounds as against 3.41 pounds for group A (lysine added). The group A pigs gained an average of 0.84 pound per day while the group B pigs hardly maintained their starting weight. In addition, the deficient pigs showed a depraved appetite, rough hair coat and symptoms of inanition (see figure 4). At the end of the 28-day lysine-deficient period, the group B pigs were given the control ration (basal+2.0% DL-lysine·HCl). The daily gain and feed consumption immediately increased and continued for the 28 days that the animals received this ration. The animals made an average daily gain of 0.77 pound and had a feed consumption of 3.05 pounds per day (see figures 1 and 2) for this 4-week period.

That lysine was the limiting factor was shown by the response of the deficient pigs when they received the ration containing lysine. The disappearance of the depraved appetite, rough hair coat and symptoms of inanition, accompanied by increases in daily gain, feed consumption and feed efficiency showed conclusively that lysine was the limiting factor in the diet.

In a previous experiment (Beeson *et al.*, 1948), pigs fed a tryptophan-deficient diet lost weight. In the present studies, the animals just maintained their body weight on a lysine-deficient ration. This may be due to the fact that a small amount of lysine (0.02%) was present in the basal diet.

The efficiency of protein synthesis in the body depends directly on protein quality and quantity in the feed when an adequate caloric intake is maintained (Cannon, 1948). Morrison (1948) gives the caloric maintenance requirements for a 50-lb. pig as 1.7 to 2.1 therms. The feed consumption of the pigs in group B (lysine-deficient) for the first 14 days was essentially identical with that of group A (basal+lysine). Yet the animals of group A gained weight while those of group B did not. The caloric intake of the lysine-deficient pigs during this period was not a limiting factor, since the animals consumed in the diet 4.2 therms per day as compared to the 1.7 to 2.1 therms necessary for maintenance (Morrison, 1948). Since the vitamin and caloric intakes of the animals were adequate for maintenance and growth, the lack of sufficient lysine apparently prevented normal protein synthesis as well as utilization of other nutrients in the deficient animals. It is now recognized that all of the essential amino acids must be present simultaneously if protein synthesis is to take place (Rose, 1928), (Berg and Rose, 1929), (Geiger, 1947), (Cannon, 1947) and (Elman, 1939).

The appetite-depressing effect of an amino acid-deficient ration is evident here when a whole protein such as zein is used. Almquist (1947) observed

this effect in chicks and rats when a mixture of amino acids or a hydrolyzed protein deficient in one essential amino acid was fed.

To obtain optimum protein synthesis and good growth in young pigs, it is essential that lysine be included among the dietary components. These data indicate that a diet containing 2.0% DL-lysine·HCl is capable of supporting growth (0.91 lb. daily) in the weanling pig.

Since corn and other cereal grains are generally low in lysine, it is necessary to supplement these feeds with proteins relatively high in lysine. This partially explains why animal proteins (which contain large amounts of lysine) are desirable in swine rations.

Summary

1. Lysine has been shown to be indispensable for the growth and development of the weanling pig.

2. A lack of lysine results results in cessation of growth, retarded feed consumption and decreased feed efficiency.

3. Lysine-deficient pigs manifest a depraved appetite, rough hair coat, emaciated look and apparent inanition.

4. A level of 2.0% DL-lysine·HCl in our experimental diet permitted an average daily gain of 0.91 lb. in pigs for the 42-day period immediately following weaning.

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EFFECT OF TRYPTOPHAN DEFICIENCY ON THE PIG[1]

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It is common knowledge that swine require proteins of high biological value for maximum growth and efficiency of food utilization. No studies have been reported on the amino acids that are essential for the growing pig, prior to a recent note by the authors (1948). Research on amino acid requirements has been confined largely to the rat (Rose, 1938), chicken (Almquist, 1947; Hegsted, 1944), dog (Rose and Rice, 1939), mouse (Bauer and Berg, 1943) and man (Rose *et al.*, 1942, 1943; Rose, 1947). Studies on the amino acid requirements of swine have been delayed until purified rations could be developed that would support normal growth in pigs. Research of Hughes (1940, 1940a), Hughes and Ittner (1942), McRoberts and Hogan (1944), Wintrobe (1938), Wintrobe *et al.* (1942) and Heinemann *et al.* (1946) have contributed substantially to perfecting purified diets that will meet the nutritional needs of the pig. Our modification of these diets has resulted in a purified ration which will produce a growth rate superior to a balanced natural feedstuff diet. This permits the study of amino acid requirements.

Luecke, McMillen, Thorp and Tull (1947) have demonstrated a relationship between nicotinic acid and tryptophan for the growing pig. Their results indicate that when corn constitutes a major part of the ration, a nicotinic acid deficiency occurs. The addition of either 30 mg. of nicotinic acid daily per pig, or 200 mg. of DL-tryptophan, alleviated the deficiency and gave a growth response. Powick *et al* (1948) showed that a nicotinic acid deficiency produced by a low nicotinic acid plus low tryptophan ration (13.81% casein + 40% corn) can be prevented by the addition of DL-tryptophan at a level of 0.25% of the diet. They concluded that nicotinic acid did not appear to be completely effective as a substitute for tryptophan, but tryptophan appeared to be, in a large measure at least, a satisfactory substitute for nicotinic acid. Thus, tryptophan is probably a precursor of nicotinic acid.

[1] Contribution from the Departments of Animal Husbandry and Agricultural Chemistry, Journal paper No. 387 Purdue University, Agricultural Experiment Station, Lafayette, Indiana.

[2] The authors are grateful to Eli Lilly and Co., Indianapolis, Indiana for the hydrolyzed fish protein and liver extract used in this study, and to A. Lee Caldwell and George Schnakenberg of the Lilly Research Laboratories for the preparation of the tryptophan-free hydrolyzed fish protein.

Experimental

Pigs used in this experiment were selected from litters farrowed by Duroc sows. The sows were fed a well-balanced natural grain ration during the gestation and lactation periods. In addition, the pigs were given access to a creep feed prior to weaning. The four male and four female pigs selected as the experimental animals were very closely related, and received identical treatment throughout the eight-week suckling period. At the end of this period, the animals were removed to the experimental barn where they were paired according to sex and weight.

The pigs were placed in individual pens equipped with raised wire screen floors. Four days were allowed for the pigs to adjust themselves to the new conditions. During this time they were fed a natural grain ration consisting of 6 parts of ground yellow corn, 2 parts of ground wheat and 2 parts of Purdue supplement 5.

An adjustment period of seven days was necessary to gradually make the change from the natural grain ration to the basal ration (table 1). By allowing this adjustment, the pigs continued to eat normally and the intestinal flora had a chance for adaptation to the new ration, thereby preventing sudden digestion and absorption disorders which could alter the normal response of the animals.

TABLE 1. COMPOSITION OF BASAL RATION (TRYPTOPHAN-LOW DIET)

Ration components	%	Vitamin supplements	Mg. daily per kg. live wt.
Hydrolyzed fish protein	26.1	1. Water-soluble vitamins	
Dextrose	30.2		
Dextrin	25.0	Thiamin hydrochloride	0.40
Lard	11.0	Riboflavin	0.12
Mineral mixture[1]	5.2	Nicotinic acid	1.20
Celluflour	2.0	Pyridoxine hydrochloride	0.20
Liver extract	0.5	Calcium pantothenate	0.50
		Choline chloride	10.00
	100.0		
			Levels daily per pig
		2. Fat-soluble vitamins	
		Vitamin A[2]	1500 I.U.
		Vitamin D[2]	200 I.U.
		Alpha tocopherol	50 mg.
		Vitamin K	2 mg.

[1] Heinemann, *et al.* (1946).
[2] Fed as Nopco XX.

The basal ration (table 1) was designed to provide a purified diet adequate in all the known nutrients excepting tryptophan. This was accomplished by modifying the ration previously reported by Heinemann *et al.* (1946). The basal diet was fed as a slop, since the hydrolyzed fish protein was in the form of a 20% water solution. It was found that the pigs would consume the slop in the same manner as if it were skim milk.

The hydrolyzed fish protein was prepared by a combination of enzymatic and acid hydrolysis to liberate and destroy the tryptophan in the fish protein. The starting material was edible cutting table waste of cooked tuna fish. This material was hydrolyzed enzymatically using the pyloric caecal mass of tuna. The resulting dried product was then treated with 5% sulfuric acid and autoclaved for 5 hours at 15 lbs. of pressure. The solution was freed of sulfate ions and treated with Norit A to remove the tryptophan decomposition products formed. A negative test for tryptophan was obtained using the colorimetric method of Horn and Jones (1945). Microbiological analysis in this laboratory showed 0.025% tryptophan present in the finished product.

The preparation of the ration consisted of heating the hydrolyzed fish protein to 50° C. at which temperature the dextrose, dextrin, mineral mixture, celluflour and lard were mixed in with constant, vigorous stirring. The preparation was stirred vigorously as it cooled to room temperature. The liver extract was then stirred in at room temperature. The vitamins were divided into two groups, the water-soluble and the fat-soluble. Each group was weighed from the purified form and mixed with dextrin as a carrier. An amount of each mixture, to supply the daily requirement of the pig, was weighed out and fed at each evening feed. The remainder of the vitamin mixture was stored in amber colored bottles in a refrigerator.

The basal diet fed to the pigs contained about 50% solids; the crude protein content of the solids in the mixture was 19.5%, the tryptophan content, about 0.01%.[3]

Results

At the start of the experiment, the pigs were healthy, thrifty animals as verified by their average weight of 50 lbs. at 60 days of age. The only variable between the diets of the two groups of pigs was the 0.4% DL-tryptophan which was added to the ration of Group A at the expense of the dextrose.

Group A (basal diet +0.4% DL-tryptophan) continued to show a rapid growth rate throughout both the adjustment period and the 28-day experimental period. This group made a daily gain of 1.42 lbs. for 28 days. The data in table 2 show that these pigs were normal. Figure 1 gives additional evi-

[3] This figure includes the tryptophan supplied by the liver extract which assayed 1.28% tryptophan by microbiological methods.

dence that the growth response was rapid. In figure 2 it is evident that the pigs fed the DL-tryptophan had a glossy, smooth hair coat and showed no visible signs of ill health or unthriftiness. The daily feed consumption and the feed efficiency were essentially the same as those obtained in a previous experiment with similar pigs on a balanced ration of natural feedstuffs. A diet containing 0.41% DL-tryptophan supplied ample tryptophan for normal growth of the pig.

Group B (basal diet only) did not receive the 0.4% DL-tryptophan in their diet. Even during the seven-day adjustment period a marked change was observed (see table 2). During this period one animal lost 4.5 lbs., one maintained his weight, and the other two made slight gains of one and two pounds respectively. It is significant to note that the animals in Group A gained an average of 6.4 lbs. during this same seven-day period. Also, it must be remembered that during this adjustment period the animals did receive a balanced natural grain ration in progressively smaller quantities, so that at the end of the week they would be receiving only the purified ration. Thus, the lack of sufficient tryptophan produced profound effects at once upon the response of the pigs. They showed considerable reduction in appetite,

TABLE 2. EFFECT OF TRYPTOPHAN ON GROWTH RATE AND FEED CONSUMPTION

Item	Unit	Ration							
		Group A Tryptophan-Added				Group B Tryptophan-Deficient			
Pig Number		1	3	5	7	2	4	6	8
Sex		M	M	F	F	M	M	F	F
Adjustment period	days	7	7	7	7	7	7	7	7
Experimental period	days	28	28	28	28	14	21	21	14
Pre-initial weight*	lb.	50.0	49.0	53.0	48.0	50.0	50.0	52.0	48.0
initial weight*	lb.	55.5	57.0	59.5	53.5	50.0	52.0	53.0	43.5
Final weight	lb.	95.0	96.5	100.0	92.5	46.5	48.5	45.5	40.0
Daily gain	lb.	1.41	1.41	1.45	1.39	−0.25	−0.17	−0.36	−0.25
Daily feed consumption	lb.	4.38	3.83	4.42	4.45	1.85	1.44	1.14	1.91
Feed per pound of gain	lb.	3.11	2.71	3.06	3.20	—	—	—	—
						Tryptophan Added			
Experimental period	days	—	—	—	—	26	19	19	26
Initial weight	lb.	—	—	—	—	46.5	48.5	45.5	40.0
Final weight	lb.	—	—	—	—	71.5	75.0	75.0	70.0
Daily gain	lb.	—	—	—	—	0.96	1.39	1.55	1.15
Daily feed consumption	lb.	—	—	—	—	3.06	3.71	3.52	3.64
Feed per pound of gain	lb.	—	—	—	—	3.18	2.66	2.27	3.15

* Pre-initial weight is the weight of the pigs at the start of adjustment period. Initial weight is that weight obtained at the end of the adjustment period. All calculations are based on the initial weight.

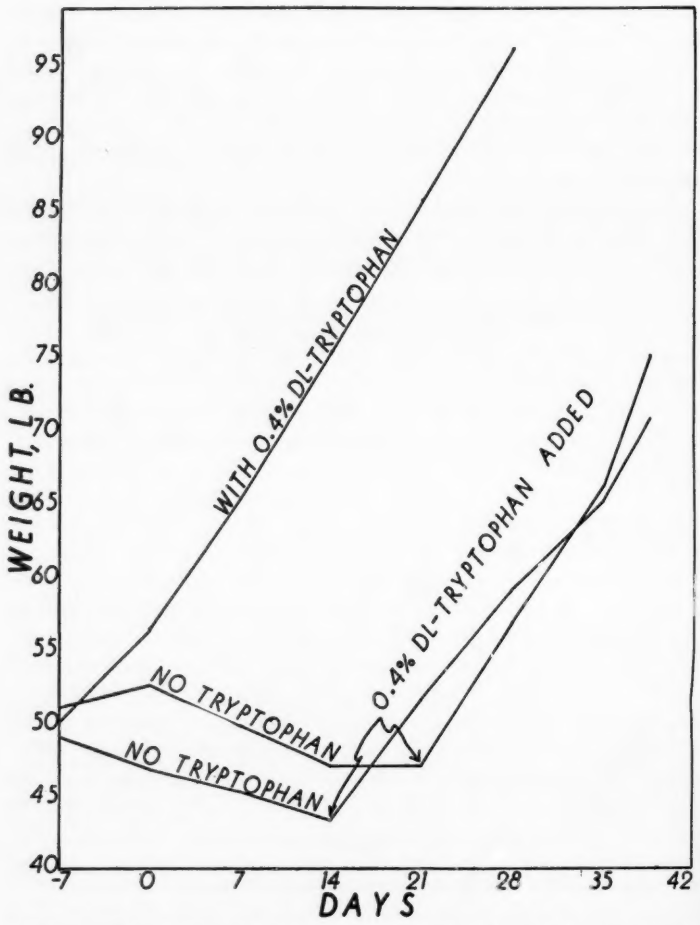

Figure 1. Growth curve of pigs to show the effect of tryptophan on growth. Note the effect during the adjustment period. The upper deficiency curve represents the response of pigs #4 and #6, while the lower curve represents the response of pigs #2 and #8 since the deficiency period varied by 7 days.

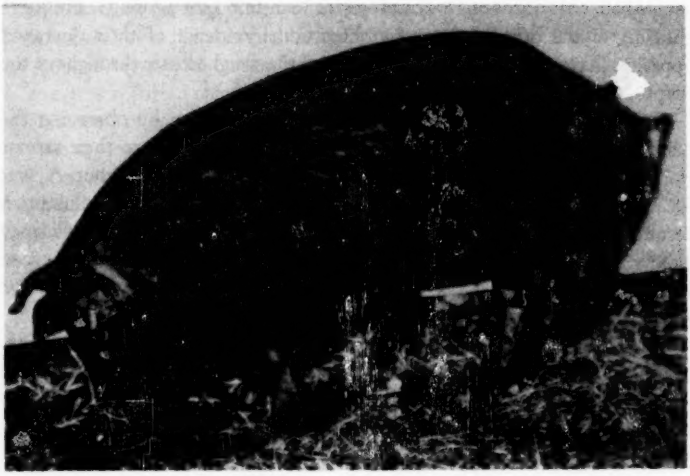

Figure 2. Pig No. 7 (basal + 0.4% DL-tryptophan) gained 25.5 lbs. in 21 days.

Figure 3. Tryptophan deficient pig No. 8 (basal diet only) lost 8.0 lbs. in 21 days.

rough hair coat and severe symptoms of inanition (see figure 3). Frequent chewing of the board fences was observed as evidence of their depraved appetites. Examination of table 2 will reveal the weight losses throughout the tryptophan-deficient period.

That tryptophan was the limiting factor was shown by observing the response of the deficient pigs when tryptophan was added to their rations (table 2). The same quantity, 0.4% DL-tryptophan, as fed to Group A, was incorporated into the rations. An immediate increase in food consumption resulted. The daily gain, the daily feed consumption and the feed efficiency closely approached that of the animals of Group A. The deficient pigs soon took on a more thrifty, healthy appearance, and gradually the gloss returned to the hair coat.

The data presented show that the removal of tryptophan has a growth-retarding effect. This experiment was designed to study the crucial period of the life of the pig immediately following weaning. The results indicate that 0.41% DL-tryptophan is sufficient to meet the requirement for this amino acid during the period investigated. There is no sex difference apparent from the observations and data obtained. The effects upon the internal organs and blood were not determined.

Discussion of Results

During the four-week trial on the purified diet, the animals in Group A made excellent gains. In a previous experiment, similar pigs gained 1.25 lbs. per day on a balanced ration of natural feedstuffs, and 1.50 lbs. per day on a purified ration with casein as the source of protein during a 42-day trial. For comparison, the animals of Group A gained 1.42 lbs. per day for 28 days.

In our experiments, the removal of tryptophan from hydrolyzed fish proteins caused an almost immediate weight loss and a curtailment of appetite. Almquist (1947) points out that the feeding of a diet containing a mixture of free amino acids deficient in one or more indispensable amino acids to chicks induces a more rapid physiological reaction to curtail appetite than does the feeding of a diet containing intact protein deficient in the same amino acids. This is presumably due to the more rapid absorption of the free amino acids. When the amino acid supply is complete, the feed intake is controlled largely by caloric requirements. In cases of amino acid deficiencies, the animal cannot dispose of absorbed amino acids by combining them into protein, and quickly becomes saturated. When the missing indispensable amino acid is added to the diet, the increase in the appetite of the animal is very evident.

Throughout the period of tryptophan deficiency, the animals lost an average of 0.25 lb. per day for the experimental period, while during a slightly longer period (28 days) the animals receiving tryptophan in their rations

gained 1.42 lbs. per day. The appetite response to the addition of tryptophan was noticed over night, which is again in agreement with the observations of Almquist (1947) on chicks. Since the deficient animal cannot build protein tissue, it is apparent that the utilization of feed would be limited to the small requirement of energy metabolism for the limited maintenance. The animals on the tryptophan deficient diet consumed approximately 1.50 lbs. of feed per day which is an adequate energy intake to maintain the body of a 50-lb. pig and support growth according to "Morrison's Standards." Therefore, it is evident that swine fed on a ration deficient in tryptophan may consume more feed than is necessary for maintenance, and yet fail to gain weight. In figure 3 is shown a pig that consumed ample feed for maintenance and some growth, yet lost weight, due to the lack of one amino acid, tryptophan. The pig exhibits all the symptoms of inanition and unthriftiness. Nineteen days after tryptophan had been added to the diet, the same pig was thriving and making normal gains.

Even though the minimum quantity of tryptophan required in the diet of the growing pig has not been determined, this important amino acid may be deficient in many swine rations. Corn, which often constitutes 60% or more of the ration, contains only 8 to 10% of crude protein, and this protein contains only 0.8% tryptophan (Block and Bolling, 1945). An animal receiving 100% corn would obtain only 8 to 10% protein, and its diet would contain a maximum of 0.08% tryptophan. To compensate for this deficiency in quantity and quality of protein, various animal and plant proteins are used as a supplement to corn.

Summary

Tryptophan has been proven indispensable for growing Duroc weanling pigs by the use of a purified diet which was deficient in this amino acid.

Lack of tryptophan decreases the feed efficiency and feed consumption, and causes a loss in weight in young pigs.

Although the minimum level of tryptophan needed for optimum growth and feed efficiency is not known, a level of 0.4% of DL-tryptophan seems to be adequate to meet the normal requirement in pigs weighing 50 to 100 lbs.

A purified diet has been formulated which supports a rate of growth equal to that obtained on a good natural grain ration.

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KNOWN AND UNIDENTIFIED FACTORS SUPPLEMENT A CORN-SOYBEAN MEAL RATION FOR WEANLING PIGS IN DRYLOT[1]

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EXPERIMENTS have been conducted at the Illinois Station on the supplementary effect of certain feeds and nutrients when added to a ration composed of corn and soybean meal fortified with minerals and vitamins A and D. Krider *et al.* (1948) obtained a significant increase in average daily gains of pigs from 32 to 75 pounds by adding six crystalline B-vitamins (B_1, B_2, B_6, pantothenic acid, niacin and choline) to this basal ration. Because the addition of 1.5% of AB liver extract to a ration composed largely of corn, soybean meal and B-vitamins was decidedly more effective in promoting gain on young pigs than additions of certain crystalline vitamins, it was concluded that the liver extract contained some factor(s) other than the vitamins tested that is essential to growing pigs.

Four experiments were conducted with weanling pigs having as their objectives; first, to study the supplementary effect of adding certain vitamins of the B-complex to a corn-soybean meal basal ration; second, to note the supplementing value of additions to this same ration of choline and dl-methionine singly and in combination; and third, to observe the supplementing value of certain natural feeds when added to this ration composed largely of corn and soybean meal plus B-vitamins as possible sources of supplementary growth factor(s) needed by weanling pigs. A preliminary report of these results was made by Dyer *et al.* (1948).

Experimental Procedure

Four tests were conducted in which weanling Duroc pigs were self-fed in groups in drylot to final weights of 75 or 100 pounds. Pigs used in these tests had been in drylot from birth to weaning (56 days) and were from sows

[1] These investigations were supported in part by funds and products contributed by the A. E. Staley Manufacturing Company, Decatur, Illinois; the Western Condensing Company, Appleton, Wisconsin; the Commercial Solvents Corporation, Terre Haute, Indiana; the Central Soya Company, Inc., Gibson City, Illinois; and, the American Dry Milk Institute, Chicago 1, Illinois. Crystalline thiamine, roboflavin, niacin, pantothenic acid, and choline chloride were supplied by the Lederle Laboratories, Pearl River, New York. Pyridoxine hydrochloride was contributed by Merck and Company, Inc., Rahway, New Jersey.

[2] The data contained in this paper are from research by the senior author in partial fulfillment of the requirements, for the Degree of Doctor of Philosophy in Animal Science.

[3] Animal Science Department, Urbana, Illinois. Acknowledgement is gratefully made for the assistance of R. H. McDade, Chief Swine Herdsman, and his associates.

that had been in drylot for one year or longer before farrowing. Criteria for allotting pigs were: previous treatment, weight, litter, sex, and condition at 56 days of age. In the assay tests, experiments 3 and 4, no pigs weighing over 35 pounds at weaning were used, since pigs that weigh 40 pounds or more at weaning tend to make rather rapid gains even on the unsupplemented basal ration. Experiment 1 consisted of 6 lots of 8 pigs each with an average initial weight of 33 pounds; experiment 2, 4 lots of 12 pigs each with an average initial weight of 31 pounds; experiment 3, 6 lots of 12 pigs each having an average initial weight of 27 pounds; and experiment 4, was composed of 5 lots of 12 pigs each with an average initial weight of 27 pounds.

TABLE 1. BASAL RATIONS FED IN FOUR GROWING-FATTENING EXPERIMENTS (1947–48, DRYLOT)

Ingredients and components of rations	Experiment numbers and treatments		
	1	2	3 and 4
Ground yellow corn, lb.	63.5	same	same
Expeller soybean meal,[1] lb.	34.0	as	as
Complex mineral mixture,[2] lb.	2.0	1	1
Fortified A and D oil,[3] lb.	0.5		
B-vitamin additions, mg. per lb. of ration			
thiamine	—	1.5	1.5
riboflavin	—	1.5	1.5
niacin	—	5.0	5.0
pantothenic acid	—	6.0	6.0
pyridoxine	—	1.5	1.5
choline chloride	—	—	250.0

[1] A blend of equal parts of 42% protein expeller soybean meal from the A. E. Staley Manufacturing Company, Swift and Company and Central Soya Company was used. The Staley soybean meal was donated by the A. E. Staley Manufacturing Company, Decatur, Illinois.

[2] Mineral mixture was composed of:

Iodized salt	25	Potassium carbonate	0.2
Steamed bone meal	31	Copper sulfate	0.1
Ground limestone	40	Manganese sulfate	0.56
Magnesium carbonate	2	Cobaltous chloride	0.1
Ferrous sulfate	1	Zinc carbonate	0.04

[3] Guaranteed to contain 2000 I.U. of vitamin A and 400 U.S.P. Units of vitamin D per gram.

Rations Fed

The basal rations used in the four experiments contained 20% crude protein and are shown in table 1. All rations were equated to contain 20% crude protein by varying the percentage of corn and soybean meal when necessary as different supplements were incorporated into the basal rations.

In the first experiment rations differed only in their content of various B-vitamins. The vitamin additions were as follows: lot 1, none; lot 2, riboflavin; lot 3, same as lot 2 plus niacin; lot 4, same as lot 3 plus pantothenic

acid; lot 5, same as lot 4 plus thiamine, pyridoxine and choline chloride; and lot 6, choline chloride. The additions per pound of diet are listed in table 2.

The basal ration in the second experiment was supplemented as follows: lot 1, none; lot 2, dl-methionine; lot 3, choline chloride; and lot 4, dl-methionine plus choline chloride (table 3).

In the third experiment different feeds were tested as sources of supplementary or unidentified growth factors. Additions to the basal ration (table 1) were: lot 1, none; lot 2, meat scraps; lot 3, dried whey-product with

TABLE 2. SUPPLEMENTING A 20% PROTEIN CORN-SOYBEAN MEAL RATION WITH CRYSTALLINE B-VITAMINS
(1947, FALL, DRYLOT)

Experiment 1

Items compared	Lot numbers and treatments					
	1	2	3	4	5	6
	Basal	Basal 1.5 mg. riboflavin[1]	Same as 2 +5 mg. niacin	Same as 3 +6 mg. pantothenic acid	Same as 4 +6 mg. thiamine +2.5 mg. pyridoxine +250 mg. choline chloride	Basal +250 mg. choline chloride
Number of pigs on test	8	8	8	8	8	8
Average initial weight, lb.	32.9	33.8	32.7	32.8	34.1	33.1
Average final weight, lb.	55.3	73.1	75.1	75.6	76.8	76.0
Av. no. days to reach final wt.	65.3	57.6	60.5	47.0	47.1	52.1
Average daily gain, lb. and standard error	.38±.12	.71±.08*	.72±.06*	.95±.07**	.95±.08**	.83±.05**
Average daily feed, lb.	1.85	2.39	2.39	2.86	2.63	2.61
Feed eaten per 100 lb. gain, lb.	540	350	341	313	290	317

* Significantly more rapid average daily gain than obtained in Lot 1 ($P \leq 0.5$).
** Highly significant over average daily gain of Lot 1 ($P \leq .01$)
[1] Vitamin additions in mg. per pound of ration.

whey fermentation solubles;[4] lot 4, meat scraps plus dried whey-product with whey fermentation solubles; lot 5, condensed menhaden fish solubles; and lot 6, penicillium meal (table 4).

The basal ration in experiment 4 was supplemented as follows: lot 1, none; lot 2, meat scraps; lot 3, dried skim milk; lot 4, meat scraps plus dried skim milk; and lot 5, condensed menhaden fish solubles (table 5). The amount of crude protein of animal origin was equated in rations fed to lots 2, 3 and 4 so that any difference in performance might be attributed to other nutrients rather than to the amount of animal protein added.

[4] Whey fermentation solubles (Ribolac.)

Results and Discussion

Experiment 1

Pigs in lot 1 exhibited rough hair coats, dermatitis, ataxia, scoured throughout the test and gained at a very slow rate as was true for pigs reported by Krider *et al.* (1948). Pigs in lots 2 and 3 made significantly faster gains than pigs in lot 1 ($P \leqq .05$), whereas pigs in lots 4, 5, and 6 gained at a highly significantly faster rate than pigs in the basal lot ($P \leqq .01$). Data in table 2 indicate that the niacin requirement of the pigs was met by the basal ration as very little difference in the average daily gain or feed efficiency occurred between lots 2 and 3. From the average daily gains of pigs in lots 4 and 5, it may be concluded that neither thiamine nor pyridoxine were in suboptimal amounts in the basal ration, although a more satisfactory feed efficiency was noted in lot 5. The results of lot 6 indicated that either choline, methionine, or methyl group donors were suboptimal in the basal ration (table 2).

The efficiency of feed utilization was satisfactory in lots 4, 5, and 6, but was very poor in lot 1. Feed consumption per 100 pounds gain was only 290 pounds in lot 5 while 540 pounds of feed were required per 100 pounds gain in lot 1.

Experiment 2

The pigs fed the basal ration, including five B-vitamins, showed no serious deficiency symptoms. However, the pigs in lot 1, without exception, had rougher haircoats and a gaunter appearance than pigs in the other three lots. Scouring was negligible and no differences in severity or duration of scouring were noted from lot to lot. As shown in table 3 pigs in lots 2, 3, and 4 gained at a highly significantly faster rate than pigs in lot 1 even though the average gain for lot 1 was 1.03 pounds per day ($p \leqq 0.01$). The average daily gain of pigs in lot 2 (0.2% dl-methionine) were not significantly more rapid than gains of pigs in lot 3 (250 mg. choline chloride per pound of ration) which from the work of McKittrick (1947) with poultry would suggest that the indispensable requirements for both choline and methionine were satisfied by the basal ration. Consequently the added choline or methionine merely met the labile methyl group needs of the pigs.

Feed efficiency was satisfactory and almost identical in each of the four lots (table 3).

Experiment 3

As in experiment 2, no marked deficiency symptoms were observed. However, pigs in lots 1, 2, and 3 were not as sleek, growthy or uniform in growth and appearance within lots as were pigs in either lots 4 or 5.

Pigs in lot 6 were sleek and exceptionally uniform in appearance but the rate of gain was somewhat lower than in lots 4 or 5 (table 4). To a final weight of 75 pounds the average daily gains of pigs in lots 4 and 5 exceeded those of lot 1 by a highly significant margin ($p \leqq 0.01$). The average daily gains of pigs in lots 2, 3, and 6 were not significantly greater than those made by pigs in the basal lot. When the test was continued to a final weight of 100 pounds, only the ration fed to lot 4 produced a significantly faster rate of gain than the basal ration. As may be seen in table 4 pigs in lots 2 and 3 gained slightly more rapidly than pigs in lot 1.

TABLE 3. CHOLINE AND METHIONINE SUPPLEMENTATION OF A 20% PROTEIN CORN-SOYBEAN MEAL RATION FOR WEANLING PIGS FED IN DRYLOT (1948, SUMMER)

Experiment 2

Items compared	Lot numbers and treatments			
	1	2	3	4
	Basal[1] (including 5 B-vitamins)	Basal+0.2% dl-methionine[2]	Basal+250 mg. choline chloride per pound of ration	Basal+0.2% dl-methionine +250 mg. choline per pound of ration
Number of pigs on test	11	12	12	11
Average initial weight, lb.	30.5	31.3	31.5	31.7
Average final weight, lb.	98.0	100.0	99.0	100.0
Average daily gain, lb. and standard error	1.03±.04	1.19±.04**	1.15±.02**	1.19±.04**
Average daily feed, lb.	2.89	3.38	3.11	3.30
Feed eaten per 100 lb. gain, lb.	285	286	274	282

** Highly significant over average daily gain of Lot 1 ($P \leqq .01$)

[1] The crystalline vitamin additions per lb. of ration were: 1.5 mg. thiamine, 1.5 mg. riboflavin, 5 mg. niacin, 6 mg. pantothenic acid, and 1.5 mg. pyridoxine.

[2] Contributed by the E. I. Du Pont De Nemours and Company, Wilmington, Delaware.

Apparently meat scraps and dried whey-product with whey fermentation solubles each contains a different growth factor(s) required for optimum performance of weanling pigs in drylot which are not amply supplied by the basal ration plus six B-vitamins. It appears that the increased growth rate of the pigs in lot 2 over those in the basal lot was due to the animal protein factor(s) contained in the meat scraps; and, that the difference in the rate of gain between lots 1 and 3 was probably due to the factor S group (whey factor) in the dried whey-product with whey fermentation solubles fed to the pigs in lot 3. A similar growth response in poultry was reported

TABLE 4. MEAT SCRAPS, FORTIFIED DRIED WHEY BY-PRODUCT, FISH SOLUBLES, AND PENICILLIUM MEAL ASSAYED FOR GROWTH FACTORS (1948, SUMMER, DRYLOT)

Experiment 3

Items Compared	Lot numbers and treatments					
	1	2	3	4	5	6
	Basal[1] (including 6 B-vitamins)	Basal+5% meat scraps[2]	Basal+2% fort. dried whey by-product[3]	Basal+5% meat scraps +2% fort. dried whey by-product	Basal+2% cond. menhaden fish solubles[4]	Basal+4% penicillium meal[5]
Number of pigs on test	12	12	12	12	11	12
Average initial weight, lb.	27.2	26.2	27.0	26.6	28.2	26.8
Average final weight, lb.	100.5	105.5	100.0	95.5	100.0	97.5
Average daily gain to 75 lbs., lb. and standard error	.98± .04	1.05± .03	1.05± .03	1.17± .05**	1.10± .02**	1.00± .03
Average daily gain to final wt., lb. and standard error	1.12± .04	1.18± .03	1.16± .03	1.26± .04*	1.19± .03	1.08± .04
Average daily feed to final wt., lb.	3.03	3.31	3.23	3.35	3.46	2.98
Feed eaten per 100 lb. gain to 75 lbs., lb.	266	265	269	245	274	238
Feed eaten per 100 lb. gain to final wt., lb.	274	283	281	268	292	

* Significantly more rapid average daily gain than obtained in Lot 1 ($P \leqq .05$).

** Highly significant over average daily gain of Lot 1 ($P \leqq .01$).

[1] Vitamin additions same as in experiment 2, table 3, plus 250 mg. choline chloride per pound of ration.

[2] Swift's 55% protein meat scraps.

[3] This 12% protein dried whey-product with whey fermentation solubles, "Pebbles' Dried Whey with Ribolac," was donated by the Western Condensing Company, Appleton, Wisconsin.

[4] Condensed Menhaden fish solubles, 33% protein, were supplied by the Central Soya Company, Inc., Decatur, Indiana.

[5] Donated by the Commercial Solvents Corporation, Terre Haute, Indiana. Penicillium meal is the suspended solids of penicillin fermentation and is tentatively defined as "Extracted Penicillium Meal." Crude protein content 39%.

by Scott *et al.* (1948). Hill (1948) working with chicks demonstrated a multiple deficiency of unidentified nutrients in a cereal-soybean meal ration. This work indicated that soybean meal is a variable source of at least one of the unidentified nutrients and that dried whey is a carrier of the factor present in variable amounts in soybean meal. The combination of meat scraps and dried whey-product with whey fermentation solubles produced a highly significant increase in the average daily gain to 75 pounds, and a significantly faster rate of gain to 100 pounds (lot 4). Hill *et al.* (1944) obtained similar responses in the growth rate of chicks by adding meat scraps to a ration which contained dried whey. Pigs in lot 5, to 75 pounds, gained significantly faster than pigs in lot 1 and a difference in hair coat and condition indicative of thrift favoring lot 5 was observed. This increase in rate of gain and thriftiness over pigs receiving the basal ration indicated that fish solubles is a good source of the supplementary growth factor(s). The animal protein factor, which contains vitamin B_{12} as a component, undoubtedly contributed to the increased growth rate in lot 5.

Analysis of the penicillium meal show that it contained the following B-vitamins, gamma per gram: riboflavin 55, niacin 195, pantothenic acid 46, folic acid 6.4, biotin 3.2 and choline 4460. Evidently this product either does not contain the unidentified growth factor(s) or does not contain a sufficient quantity of them to give increased growth under these conditions (lot 6).

Feed efficiency was satisfactory in all lots (table 4).

Experiment 4

In this experiment differences in haircoat and rate of gains were observed, with the lots ranking in the order of 3–4–5–2–1. The difference in rate of gain between lots 1 and 3 was highly significant in favor of lot 3 at final weights of both 75 and 100 pounds (table 5). The same was true for lot 5 over lot 1 to a weight of 75 pounds but not to 100 pounds. Significantly more rapid gains were made by the pigs of lot 4 than by those of lot 1 to both weights.

Dried skim milk alone fed as 8% of the ration (lot 3) or half that amount fed with 2.5% of meat scraps (lot 4) promoted somewhat more rapid gains than 2% of condensed menhaden fish solubles (lot 5) but these differences were not significant. Skim milk is known to be a carrier of both the animal protein factor and factor S. Although fish solubles contain both of these factors, the rate of gain of pigs fed this product was slower than when dried skim milk was fed probably because 2% condensed menhaden fish solubles was an inadequate amount to furnish the optimum amount of the growth factor(s). Other growth tests with weanling pigs fed in drylot at

TABLE 5. DRIED SKIM MILK, MEAT SCRAPS AND FISH SOLUBLES ASSAYED FOR GROWTH FACTORS NEEDED FOR OPTIMUM GROWTH OF WEANLING PIGS (1948, SUMMER, DRYLOT)
Experiment 4

Items compared	Lot numbers and treatments				
	1	2	3	4	5
	Basal[1] (including 6 B-vitamins)	Basal +5% meat scraps	Basal +8% dried skim milk[2]	Basal +2.5% meat scraps+4% dried skim milk	Basal +2% condensed menhaden fish solubles
Number of pigs on test	12	12	12	11	11
Average initial weight, lb.	27.2	26.2	26.8	26.7	28.2
Average final weight, lb.	100.5	105.5	101.0	97.3	100.0
Average daily gain to 75 lbs., lb. and standard error	.98± .04	1.05± .03	1.14± .04**	1.12± .05*	1.10± .02**
Average daily gain to final wt., lb. and standard error	1.12± .04	1.18± .03	1.26± .03**	1.24± .04*	1.19± .03
Average daily feed to final wt., lb.	3.03	3.31	3.44	3.19	3.46
Feed eaten per 100 lb. gain to 75 lbs., lb.	266	265	230	226	274
Feed eaten per 100 lb. gain to final weight, lb.	274	283	277	259	292

* Significantly more rapid average daily gain than obtained in Lot 1 ($P \leqq .05$)
** Highly significant over average daily gain of Lot 1 ($P \leqq .01$)
[1] Vitamin additions same as in experiment 2, table 3, plus 250 mg. choline chloride per pound of ration.
[2] Swift's 55% protein meat scraps.

the Illinois Station indicated that 2% of this sample of condensed menhaden fish solubles did not produce optimum growth when it was added to another ration without any crystalline B-vitamins added (unpublished data). Two percent of another sample of condensed fish solubles has produced as rapid gains as when 4% was fed. Work with rats by Cary and Hartman (1947) and others has shown that skim milk contains an unidentified growth factor(s) which is not present in ground yellow corn or soybean meal.

Feed efficiency was satisfactory in each of the five lots (table 5).

Summary

A 20% crude protein ration composed largely of corn and soybean meal was nutritionally inadequate for weanling pigs in drylot. The addition of either 1.5 mg. riboflavin, 6 mg. pantothenic acid or 250 mg. choline chloride per pound of ration significantly increased the average daily gains, while neither thiamine, niacin nor pyridoxine as additions to the basal ration had a significant effect on the rate of gain.

When the basal ration included five B-vitamins, the addition of either 250 mg. choline chloride per pound of ration or 0.2% dl-methionine or a

combination of both very significantly increased the growth rates. The choline-methionine combination produced results which did not differ significantly from those obtained when either choline or methionine was fed. This indicates that the basal ration satisfied the indispensable choline and methionine requirements of the pigs but did not provide enough additional methyl groups for optimum growth.

When the basal ration included six B-vitamins, the addition of either 5% meat scraps or 2% dried whey-product with whey fermentation solubles increased the average daily gains, although not significantly. Either 5% meat scraps plus 2% dried whey-product with whey fermentation solubles or 2% condensed menhaden fish solubles resulted in a highly significant increase in growth rate to 75 pounds. The average daily gain to 100 pounds was increased appreciably by the 2% fish solubles, but the increase was not statistically significant. The addition of 4% penicillium meal did not improve the rate of gain. The addition of 8% dried skim milk resulted in a highly significant increase in the growth rate to 75 and 100 pounds, while the addition of 4% dried skim milk plus 2.5% meat scraps significantly increased the rate of gain both to 75 and 100 pounds. Performance of pigs in these tests indicates that meat scraps is probably a source of the animal protein factor(s), that dried whey-product with whey fermentation solubles contains the factor S group and that the combination of these two feeds, condensed menhaden fish solubles and dried skim milk contain both the animal protein and factor S groups. These responses of pigs are similar to those reported in poultry researches.

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THE EFFECTS OF GONADOTROPHINS ADMINISTERED TO SOWS AND GILTS DURING DIFFERENT STAGES OF THE ESTRUAL CYCLE[1]

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PREVIOUS work has shown that in cattle (Casida *et al.*, 1943), sheep (Murphree *et al*, 1944) and rabbits (Murphree *et al.*, 1947) ovulation can be induced experimentally in both the luteal and follicular phases of the reproductive cycle. The ova produced during the luteal phase, however, have shown a very low incidence of fertilization in all species. Boyarsky *et al.* (1947) have shown this tc be due to the action of progesterone.

The present study deals primarily with (1) the number of ovulations which can be induced in swine during the follicular and luteal phases of the estrual cycle by injections of gonadotrophins and (2) the percentages of the resulting eggs which can be fertilized. In addition, during the course of the study, it was necessary to give consideration to (1) the place of deposition of semen in the sow's genital tract (2) the nature of the gonadotrophic action of pregnant mare serum (PMS), during the luteal phase of the estrual cycle and (3) the time of ovulation after intravenous injection of unfractionated sheep pituitary extract.

Gonadotrophic Action of PMS; Place of Deposition of Semen

Most of the work with cattle, sheep and rabbits has involved superovulation. This was brought about by pretreating the animals with a follicle-stimulator before the ovulation stimulus was given. Pregnant mare's serum was an available source of follicle-stimulator for the present study. While PMS is follicle stimulating in action in cattle during the luteal phase (Folley and Malpress, 1944), it was unknown whether similar action occurs during the luteal phase in swine. Further, since such treatment likely would not induce estrus, another, question arose whether by artificial insemination or by "forced-mating," semen actually would be deposited in the uterus of luteal animals, as appears to be the case in estrual animals (Milovanov, 1932; Rodolfo, 1934).

Therefore, four sows (two Chester Whites and two Poland Chinas) were injected intramuscularly with 2000 I. U. of PMS on day-5 of the estrual cycle, to simulate the treatment to be imposed on the experimental sows,

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and were bred and slaughtered on day-10. Two of the sows were force-mated and slaughtered within 30 minutes. The reproductive tracts were removed within 45 minutes after mating, and the oviducts were severed immediately from the uterine horns at the tubal junction. In both sows a gelatinous seminal plug was found in the cephalic region of the cervix, and in one animal it extended through the uterine body and a short distance into each horn, effectively preventing the backflow of semen. Rodolfo (1934) observed vaginal plugs in estrual sows. The entire length of each horn in both sows, and the uterine body in one sow, was markedly distended with seminal fluid containing tapioca-like pellets. No noticeable peristaltic movements of the uterus were observed under this seminal distension. The oviducts were severed from the uterine horns within 45 minutes after forced-mating and smears made of the tubal contents at different regions indicated the presence of sperm in the caudal region of the oviduct in one sow and in the cephalic region in the other.

The other two sows were artificially inseminated with 75 cc. undiluted semen (exclusive of the gelatinous constituents); the anterior end of the insemination tube appeared to extend into the cephalic portion of the cervix. The sows were slaughtered immediately, and the tracts were removed within 15 minutes after insemination, at which time the oviducts were severed from the uterine horns. Neither the uterine body nor the horns were distended with semen as observed in natural mating. Instead, a thin film of semen was seen throughout the length of the horns. The uterine horns in these sows showed very marked peristaltic contractions. These waves would appear and disappear independently and simultaneously at several different regions along the horns, some ascending, others descending.

Whether due to the lesser volume of semen, a more caudal site of deposition, or the shorter interval from the time of insemination to slaughter, or a combination of these factors, spermatozoa had not entered the oviducts as they had in the sows which were mated naturally: they had progressed, however, to the tubal junctions in both sows. Rodolfo (1934) found that spermatozoa entered the Fallopian tubes within 40 minutes after a sow in heat was artificially inseminated. Thus, no evidence was found to refute the idea that the transport of sperm through the uterus is equally rapid in non-estrual and estrual sows.

Observations on the ovaries of these four sows gave evidence as to the nature of the gonadotrophic action of pregnant mare serum. No ovulations were observed in any of the sows at the end of the 5-day post-treatment interval. An average of 27.3 follicles 8–11 mm. in diameter per sow was found, thus indicating that PMS was largely, if not solely follicle-stimulating in action during the luteal phase.

Ovulation and Fertilization in Follicular and Luteal Phases (Trial 1)

In the light of the results of the preliminary studies it appeared that sperm were deposited into the uterus of the luteal phase sow. Furthermore, PMS could be used as a follicle stimulator without producing ovulation, and thus make it possible to inseminate the experimental animals at the optimal time after administering an ovulation stimulus. A trial was then conducted during the summer of 1947 in which ovulation and fertilization were studied in 18 yearling sows (nine purebred Chester Whites and nine purebred Poland Chinas); nine of these were in the luteal and nine in the follicular phase of the estrual cycle at the time of treatment. Estrual behavior

TABLE 1. OVULATION AND FERTILIZATION IN GONADOTROPHIN-TREATED SOWS
(Trial 1)

Phase when treated	Total number of sows	Number sows in which estrus occurred	Average number ovulation points	Average number ova fe-covered	Average number ova fertilized	Average number follicles (8 mm. and over)	Number sows showing	
							Egg plugs	Uterine seminal residues
Luteal	9	0	13.0	10.6	0.0	4.8	6	7
Follicular	9	5	25.3	19.6	5.3	4.2	3	2

was checked each morning by the use of a vasectomized boar. A dosage of 2000 I. U. of pregnant mare serum[2] was administered intramuscularly on day-5 of the estrual cycle in the luteal group and on day-16 in thefollicular group. This was 5 days before ovulation was induced by an intravenous injection of unfractionated sheep pituitary extract (1 gm. equivalent).[3] All sows were either fore-mated or artificially inseminated at the time of the intravenous injection and in some instances again 6–20 hours later. The animals were slaughtered 48 to 56 hours after the ovulating treatment. The oviducts were removed and flushed with physiological saline to recover the ova, and fertilization of the eggs was determined by the presence of two or more blastomeres of equal size (cleavage).

At no time between treatment and slaughter did any of the sows in the luteal group show estrual behavior, while five of the follicular group came into estrus (table 1) The luteal sows showed a lesser ovarian response than did the sows of the follicular group. There was an average of 13.0 ovulation points per luteal sow, as compared with 25.3 per follicular sow. Cleavage

[2] Acknowledgment is made to the Upjohn Company, Kalamazoo, Michigan, for supplying "Gonadogen."
[3] The authors are indebted to Dr. W. H. McShan, of the Zoology Department, University of Wisconsin, for the preparation of hormone extracts.

did not occur in any of the ova of the luteal sows although sperm were observed in the zona pellucidas of two of the 97 recovered ova. An average of 5.3 fertilized ova was recovered from the follicular sows. Fertility in the follicular group, however, was extremely variable, occurring in only four of the nine sows and showed no association with the occurrence of heat.

The completeness of ovulation in the luteal sows was comparable with that of the follicular sows, as borne out by the average number of follicles 8 mm. and over remaining in the ovary. There was an average of 4.8 unovulated follicles per luteal sow as compared with 4.2 per follicular sow.

A marked contrast was observed in the condition of the uteri of the luteal sows and of the follicular sows, which may indicate a difference in the rate of absorption or evacuation of seminal residue from the uterus. A heavy greenish-yellow fluid containing tapioca-like pellets was observed throughout the entire length of the uterine horns in seven of the nine luteal sows, while only two follicular sows showed such uterine contents and they to a lesser degree.

A phenomenon, not previously noticed in this laboratory in hormonally-treated sheep and cattle, appeared in the sows—the occurrence of a gelatin-like plug in the oviducts which entrapped the ova. This plug was more consistent and definite in the luteal sows where it was found in six out of the nine animals and in every case enclosing practically every egg. In the follicular group only traces of its occurrence were observed in three of the nine sows, and here was enclosed only one or a few ova.

Time of Ovulation After Injection of Hormone

The occurrence of egg plugs somewhat similar to those observed after very recent ovulation in rabbits and rats (they have since been observed in normal sows which have recently ovulated) suggested that ovulation occurs later after the intravenous injection than was anticipated. The time of insemination and of slaughter of the animals may not have been optimal in the first trial, consequently additional studies were made during the following winter months to determine the time of ovulation when the stimulus of an intravenous injection of pituitary extract was given at different stages of the estrual cycle.

A group of 27 gilts (18 grade Chester Whites, 9 grade Poland Chinas) were allotted equally to one luteal and two follicular groups. The standard treatment, consisting of a single intravenous injection of unfractionated sheep pituitary extract, was instituted on day-6 of the cycle in the luteal group and on day-17 and day-20 in the two follicular groups, respectively. To simulate the conditions of Trial I, relative to the possible stimulus to ovulation which may arise from insemination, all animals were artificially

inseminated at the time of the intravenous injection. Within each group the gilts were then slaughtered 24, 36, or 48 hours after the intravenous injection.

Regardless of the stage of the cycle, no ovulations occurred as early as 24 hours after the intravenous injection (table 2). The early stages of the ovulation interval were just reached in all three groups by 36 hours after injection time, since approximately one-half of the gilts showed no ovulation, and the remainder showed partial ovulation. No gilt at this interval after injection had completely ovulated. By 48 hours after injection, the latter stages of the ovulation interval were reached. Two-thirds of the gilts

TABLE 2. COMPLETENESS OF OVULATION AT VARIOUS INTERVALS AFTER INTRAVENOUS INJECTION OF UNFRACTIONATED PITUITARY EXTRACT

Day of cycle when treated	Slaughter time (hours after injection)	Total number gilts	Number of gilts showing:			Average number ovulation points	Average number follicles (8 mm. and over)	Number of gilts showing ova plugs
			No ovulation	Partial ovulation*	Complete ovulation*			
6	24	1	1	0	0	0	0	0
	36	4	2	2	0	1	4.0	0
	48	4	1	1	2	5	2.0	2
17	24	1	1	0	0	0	0	0
	36	4	3	1	0	1.3	0	1
	48	4	0	2	2	9.3	4.3	4
20	24	1	1	0	0	0	10	0
	36	4	2	2	0	2.5	10.5	1
	48	4	0	0	4	13.0	0.3	2

* Ovulation was considered partial if unruptured follicles 8 mm. or more in diameter were present along with ovulated follicles; it was considered complete if no more than one unruptured in addition to the ruptured follicles was present.

in the various "day-groups" had completely ovulated, while another quarter had partially ovulated.

The possibility of a difference in the time of ovulation between animals treated during the luteal phase and those treated during the follicular phase, as suspected, was not borne out. Although no apparent difference in ovulation times was observed, the average number of ovulations increased progressively as the cycle advanced. Averages of 5.0, 9.3 and 13.0 ovulation points were counted in the 48-hour gilts treated on days-6, -17 and -20 of the cycle, respectively. The appearance of ova plugs in the tubal flushings was encountered at these short intervals after ovulation, both in the luteal and follicular groups alike. Finally, the time of ovulation was found to be much later than was assumed from our knowledge of other species in planning Trial I.

Ovulation and Fertilization in Follicular and Luteal Phases (Trial 2)

The fact that ovulation occurs 36–48 hours after administration of the ovulation stimulus definitely raised the question of whether or not in Trial I the later-than-expected time of ovulation prevented the elapse of a sufficient interval for cleavage to be manifested by the time of slaughter. As a consequence, another trial seemed desirable. First, however, in a preliminary study two gilts were given an intravenous injection on day-6 of the estrual cycle, inseminated 24 to 29 hours after injection and killed 83 hours following injection. One gilt had two fertilized eggs out of six recovered and the other

TABLE 3. OVULATION AND FERTILIZATION IN GONADOTROPHIN-TREATED GILTS
(Trial 2)

Phase when treated	Total number of gilts	Number gilts in which estrus occurred	Average number ovulation points	Average number ova recovered	Average number ova fertilized	Average number follicles (8 mm. and over)	Number gilts showing	
							Egg plugs	Uterine seminal residues
		(PMS plus pituitary extract)						
Luteal	4	0	28.8	16.0	0.0	7.8	3	3
Follicular	4	3	27.3	16.5	8.3	4.5	0	0
		(Pituitary extract only)						
Luteal	4	0	3.3	2.5	0.5	4.0	2	3
Follicular	4	0	17.0	16.8	6.5	1.5	3	0

only one unfertilized egg and no fertilized. The second trial was then designed to study at a more optimal interval after treatment the differences in the incidence of fertilization in the follicular and luteal animals.

This trial involved 16 gilts which were divided into 4 groups, each containing 2 grade Chester White and 2 grade Poland China. Two of the groups were treated (table 3) with the intravenous injection of pituitary extract only, administered on day-10 to the luteal group and day-17 to the follicular group. The other two groups received an injection of PMS on day-5 or day-16 and their respective pituitary injections on day-10 or day-21. Artificial insemination was performed for the most part at 24 to 36 hours after injection. From two to five inseminations were made on each gilt at 12 to 24 hour intervals. Every effort was thus made to have viable sperm present at the time of ovulation. The time of slaughter, which was later than in the first experiment, ranged from 60 to 108 hours after the intravenous injection.

No luteal gilt treated with PMS came into estrus, while three of the four follicular gilts manifested estrual behavior. Differing from the results with the sows of Trial I, the average number of ovulation points was approximately the same for the luteal gilts (28.8) as for the follicular gilts (27.3). The average number of ova recovered per gilt, likewise, was equal for the luteal and follicular group (16.0 vs. 16.5). Again no fertilized ova were recovered from gilts of the luteal group, while an average of 8.3 was found per follicular gilt. Although the number of ovulation points per gilt for the two groups was equal, the response to the ovulating treatment was not as complete in the luteal gilts as in the follicular gilts, as indicated by the number of unovulated follicles (7.8 vs. 4.5). Gelatinous plugs and uterine seminal residues were found only in the sows of the luteal group. Thus, except for the disparity in (1) the number of ovulation points and (2) the completeness of the response to the ovulation stimulus between the luteal and follicular group, the results obtained with gilts treated with PMS corroborated the findings with sows receiving the identical treatment (Trial I) as is evident in the comparison of the two groups (tables 1 and 3).

Under the omission of PMS with only the administration of unfractionated sheep pituitary extract, neither group of gilts displayed signs of estrual behavior. The average number of ovulation points per gilt of the luteal group was markedly lower than that for the follicular group (3.3 vs. 17.0); one of the four luteal gilts failed to ovulate. The average number of ova recovered was also lower in the luteal gilts than in the follicular gilts (2.5 vs. 16.8). That fertilization is possible during the luteal phase was again established in this group of gilts, but the incidence of it was exceedingly low, 0.5 per luteal gilt as contrasted to 6.5 per follicular gilt. The average number of follicles 8 mm. and over was much higher in the luteal gilts than in the follicular gilts (4.0 vs. 1.5). Gelatinous ova plugs occurred in the follicular gilts as well as luteal gilts. However, uterine seminal residues were found only in luteal gilts.

Summary

The effects of gonadotrophins administered during different stages of the estrual cycle were studied in 22 sows and 45 gilts. Both purebred and grade Poland Chinas and Chester Whites were used.

Both artificial insemination and natural mating resulted in semen being deposited directly into the uterus of the sow in the luteal phase of the estrual cycle.

Seminal residues persisted for a longer time in the uterus of the luteal phase sow than in that of the follicular one.

Ovulation occurred 36–48 hours after an intravenous injection of sheep

pituitary extract whether administered on the 6th, 17th, or 20th day of the estrual cycle.

The intravenous injection when given alone resulted in a larger number of ovulations when administered to gilts in the follicular phase than to those in the luteal phase. When this injection followed treatment with PMS there was a similar difference between the phases in the sows but not in the gilts. This apparent age difference is not explained.

A marked difference in the incidence of fertilized eggs occurred between animals treated in the two phases : Avg. 5.3 in the follicular as contrasted to 0.0 in the luteal in one trial and 8.3 and 6.5 as contrasted to 0.0 and 0.5 in another.

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A STUDY OF IMPAIRED FERTILITY IN FEMALE SWINE

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POOR reproductive performance in certain selected lines of swine at the University of Illinois prompted a study of the occurrence of anatomical or physiological abnormalities of their reproductive organs. A search of the literature did not reveal any systematic studies of the frequency of abnormalities in swine and the extent to which these abnormalities impair fertility or cause complete sterility. In order to obtain information on these questions an experiment was begun by the University of Illinois and preliminary results were reported by Green and Nalbandov (1948), and Wilson, Nalbandov and Krider (1948). A similar study was initiated at the University of Wisconsin and their results were reported by Warnick, Grummer and Casida (1947 and 1948), and by Wiggins, Casida and Grummer (1948).

Materials and Methods

During the winter and spring seasons of 1948 and 1949 a total of 66 gilts and 29 sows which were thought to be hard to settle or sterile were obtained from the herds of Illinois swine producers and from the University of Illinois. These females were assembled for study because they had failed to settle after being bred in an average of 2.8 heat periods to an average of 1.6 boars. The boars used by the cooperators had settled other females during the same breeding season and were therefore thought to be fertile. Females of six breeds were represented: Hampshire, Duroc, Poland China, Chester White, Yorkshire and Berkshire.

Detailed reproductive histories on each female were supplied by the owners. In almost all cases the histories were copied from written records, although in a few cases reliance had to be placed on the memory of the producers. Data regarding the total number of females bred each season and the number of those not settling were also furnished by the cooperating producers.

Only apparently healthy animals were accepted for the study and, as a general rule, the female had been tested for brucellosis by the producers. Approximately one-half of the females, which were obtained during the fall and winter of 1947–1948, and all of the females obtained during the fall and

[1] Part of the thesis submitted by the senior author for the degree of Doctor of Philosophy who is now at South Dakota State College of Agriculture and Mechanic Arts, Brookings, South Dakota.

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winter of 1948–1949 were checked for brucella infection at the time of arrival at the University, and infected females were eliminated.

Females which were a year and a half of age or younger at the time were placed on the experiment and had not farrowed a litter were classified as gilts. All sows had produced one or more litters prior to being placed on study.

The boars used in this study were Hampshires whose fertility was checked repeatedly during the progress of the experiment. They were tested for brucellosis at approximately three-month intervals during the study and all were negative.

TABLE 1. PERFORMANCE OF ANIMALS DURING EXPERIMENT

No. of females	No. of heats at which bred	Av. no. of days from last heat to slaughter	Remarks
38	1	38.1	Pregnant
4	2	45.3	Pregnant
2	1	48.0	Not pregnant; 1 cystic, 1 resorption
3	2	3.0	Not pregnant; no abnormalities
8	2	3.4	Not pregnant
10	2	3.0	Not pregnant
1	3	3.0	Not pregnant — Anatomical or physiological
7	3	3.1	Not pregnant — abnormalities present.
2	4	3.3	Not pregnant
1	0	—	Not pregnant
3	Slaughtered before pregnancy could take place		

Of the 95 females obtained for study 13 were found to be pregnant when placed on experiment. They had conceived either during the last heat in which bred prior to being culled or had been bred without the knowledge of the producers. Three females were eliminated from the study because of apparent infections. One female did not come in heat prior to or during the study. The remaining 78 females were bred during their first heat period after being placed on the study and if they showed no subsequent heat they were assumed to have conceived and were slaughtered. Those females which returned to heat were rebred and slaughtered one to two days after the end of heat. The pertinent data concerning these animals are shown in table 1.

The period of one to two days after the end of heat was chosen as the opportune time for slaughter for those females which did not conceive because at this time it was possible to obtain ovulated eggs from the oviducts by flushing. Microscopic examination of eggs thus obtained was made to determine whether or not the eggs were fertilized.

Each female was given as many services by each of at least two boars during a heat period as was possible, depending upon the number of females in heat at that particular time. Each boar was allowed to perform only two services per day—one in the morning and one in the afternoon at the time when the females were checked for heat. The duration of heat was determined by the acceptance of service.

At slaughter the genital tracts were studied grossly for possible causes of sterility and reduced fertility due to anatomical obstructions, malfunctions, deformities and injuries.

Results and Discussion

Over half (53.2%) of the 79 females (table 2) settled to the boars used in the study and had normal embryos when slaughtered an average of 38.9 days after being bred. About half of the 79 females (48.1%) conceived from services in the first estrus in which they were bred on experiment. Abnormal conditions of the genital tracts were present in 7.1% of the pregnant females.

TABLE 2. RESULTS OF STUDY WITH "HARD TO SETTLE" GILTS AND SOWS

Females showing:	Gilts		Sows		Total	
	No.	%	No.	%	No.	%
Pregnancy	23	45.1	19	67.8	42	53.2
No abnormalities	(21)	(41.1)	(18)	(64.3)	(39)	(49.4)
Abnormalities	(2)	(4.0)	(1)	(3.6)	(3)	(3.8)
No pregnancy	28	54.9	9	32.2	37	46.8
No abnormalities	(3)	(5.9)	(1)	(3.6)	(4)	(5.0)
Abnormalities	(25)	(49.0)	(8)	(28.6)	(33)	(41.8)
Total	51	100.0	28	100.0	79	100.0

The remaining 37 females (46.8%) did not become pregnant. Autopsy disclosed that their reproductive tracts had various types of abnormalities which were grouped into nine categories, most of which would seriously reduce the reproductive efficiency of the females (table 3). According to the type of abnormality found fertilization was held to be either possible or unlikely and the condition of the reproductive tracts was classified accordingly. In only four animals (5%) could no anatomical or physiological reason for sterility be found.

A classification of the genital tracts shows that 47.1% of the gilts and 67.9% of the sows had no gross abnormalities. Fertilization was judged

TABLE 3. CONDITION OF THE REPRODUCTIVE TRACTS OF "HARD TO SETTLE" GILTS AND SOWS

Condition of tract	Gilts		Sows		Total	
	No.	%	No.	%	No.	%
No gross abnormalities present	24	47.1	19	67.9	43	54.4
Gross abnormalities present						
Fertilization possible	9	17.6	6	21.4	15	19.0
Unilateral missing segment	(1)	(2.0)	(1)	(3.6)	(2)	(2.5)
Cystic follicles plus corpora lutea	(4)	(7.8)	(2)	(7.1)	(6)	(7.6)
Cystic in inner wall of pelvic cavity, pus in one uterine horn	(0)	(0.0)	(1)	(3.6)	(1)	(1.3)
Evidences of complete resorption	(0)	(0.0)	(1)	(3.6)	(1)	(1.3)
Unilateral blind segment	(4)	(7.8)	(1)	(3.6)	(5)	(6.3)
Fertilization unlikely	18	35.3	3	10.7	21	26.6
Hydrosalpinx and pyosalpinx	(16)	(31.3)	(1)	(3.6)	(17)	(21.5)
Blind uterine body	(1)	(2.0)	(0)	(0.0)	(1)	(1.3)
Bilateral cystic follicles with no corpora lutea	(0)	(0.0)	(2)	(7.1)	(2)	(2.5)
Infantile reproductive tract	(1)	(2.0)	(0)	(0.0)	(1)	(1.3)
Total	51	100.0	28	100.0	79	100.0

possible in 41.7% of the females having gross abnormalities and was held to be highly unlikely or impossible in 58.3%.

A comparison of the fertility of gilts and sows shows that in the females which did not settle, fertilization could have taken place in 43.2% of the females but was not likely to have happened in the remaining 56.8% (table 4). In the group which became pregnant normal fertility was likely in 92.9% of the females and in 7.1% the fertility level was likely to be impaired.

TABLE 4. COMPARISON OF FERTILITY OF GILTS AND SOWS BRED DURING ONE OR MORE HEAT PERIODS

Females	Did not become pregnant				Become pregnant			
	Fertilization likely		Fertilization unlikely		Normal fertility likely		Impaired fertility likely	
	No.	%	No.	%	No.	%	No.	%
Gilts	10	37.0	17	63.0	21	91.3	2	8.7
Sows	6	60.0	4	40.0	18	94.7	1	5.3
Total	16	43.2	21	56.8	39	92.9	3	7.1

From the data supplied by the cooperating producers it appears that only about 6.3% of the females were culled from their herds as sterile or hard to settle. This figure is probably too low since no attempt was made to obtain any information from the producers on the actual number of females which farrowed. Without doubt not all the females which were recorded as having settled, produced litters and some were eliminated without our knowledge.

Discussion

The most common abnormalities observed involved the oviducts. Various kinds and degrees of tubal abnormalities were observed (figures 1 and 2). In practically every female this condition was found bilaterally but the two oviducts were not always affected to the same extent. Some oviducts were not noticeably distended but contained purulent material while others were distended to over an inch in diameter.

In those cases where the oviducts were distended with fluid there appeared to be a section, usually in the uterine third of the oviduct, which was blocked. In those cases where the oviduct appeared to be patent, a light yellow material was flushed from the lumen. This material prevented the ova from passing through the oviduct. Several females were slaughtered at a time when the ova would have been expected to be in the oviducts and possibly in the uteri; however, the ova were flushed off the ovary and off the inner lining of the fimbria thus indicating that ovulation was not impaired but that the ova could not enter the oviduct because it was blocked by purulent material. Usually, considerable pressure was required to force the flushing fluid through such oviducts. Tubal abnormalities, such as these, would appear from this evidence to prevent the passage of ova and sperm through the oviducts. In most cases of hydrosalpinx and pyosalpinx adhesions of the fimbriae to the ovaries were present. Evidences of fimbrial adhesions were also noted in some females with cystic ovaries.

Tubal abnormalities were found in 31.3% of the gilts and only in 3.6% of the sows (1 case). Another case was found in one sow on another study. Both of these sows had farrowed litters. The causes of hydrosalpinges are not known and attempts to produce them experimentally were not wholly successful. It is interesting to note that this condition occurred with greater frequency in gilts than in sows.

Cystic follicles were the second most common abnormality observed (figure 3). In this study follicles measuring 14 mm. and over in diameter were grossly classed as cystic. While normal follicles frequently reach the size of 14 mm. in diameter, histological evidence indicates (Green and Nalbandov, unpublished) that in many instances, and particularly in animals showing reproductive failures, follicles of this size show signs of abnormality

Figure 1. Hydrosalpinges involving oviducts and fimbriae with adhesions to ovaries.

Figure 2. Unilateral hydrosalpinx with adhesions to left ovary, pyosalpinx on right side.

Figure 3. Cystic ovaries and hydrosalpinges.

Figure 4. Ruptured culs-de-sac leading to inflammation of Bartholin's glands.

and must be classed as cystic. In the majority of the females used in this study, however, the size of the cysts was far in excess of the 14 mm diameter used as the lower limit. Cystic follicles were observed in the ovaries of pregnant and non-pregnant animals. The presence of cysts does not prevent normal-sized follicles from ovulating. Fertilized ova were recovered from some of the cystic females. On another study two females which were suspected of having cystic follicles were operated upon and their ovaries were found to contain cysts. These sows, after recovering from the operation, were allowed to run with a fertile boar for about three months. When

TABLE 5. COMPARISON OF ESTRUS AND ESTRUAL CYCLES OF CYSTIC AND NON-CYSTIC FEMALES (A COMPOSITE OF TWO STUDIES)

Items	Females with cystic follicles	Females without cystic follicles
Length of estrual cycle		
Gilts, number	8	31
Average length, days	21.19*	19.56
Standard deviation, days	± 2.88	±1.80
Sows, number	11	49
Average length, days	25.23	20.25
Standard deviation, days	±11.99	±4.47
Length of estrual period		
Gilts, number	8	31
Average length, days	2.02	2.10
Standard deviation, days	± 0.83	±0.75
Sows, number	11	49
Average length, days	2.42	1.98
Standard deviation, days	± 0.09	±0.84

* P = ≦0.05.

slaughtered, approximately six months after the operation, one had seven normal fetuses and no cystic follicles. The other sow was sold on the market about 90 days before parturition. This may indicate that cystic follicles do not necessarily render females permanently sterile but may prevent them from settling until the ovaries return to normal.

Cystic follicles could be predicted in living animals with a certain degree of accuracy. Several cystic females during their heat periods acted like a very aggressive boar. These females, when in heat, tended to mount other females regardless of whether the latter were in heat or not. When boars were turned in the lot with cystic females, which were in heat, it was quite a task to keep them away from a boar long enough to allow him to serve a

female. The estrual cycles of cystic females were very irregular, generally somewhat longer than usual, but short cycles of as few as nine days were not uncommon. The length of the heat period of cystic females was also irregular, being either abnormally long or abnormally short. Comparison of the length of the estrual cycle and the duration of heat of cystic and non-cystic females shows that the cycles of cystic gilts were significantly longer than those of non-cystic gilts (table 5). The length of the cycles of cystic sows was longer than non-cystic sows, but not significantly so. The duration of estrus of the two groups of gilts and of sows was also not significantly different. In addition to the behavioristic peculiarities of cystic females and the irregularities of their cycles and estrual periods, about half of them could be detected, while alive, by the examination of the clitoris which was found to be enlarged. Details of this study will be presented in a subsequent paper.

In addition to hydrosalpinges there are other anatomical abnormalities which lead to complete or partial sterility. Such abnormalities have included cases in which, one uterine horn, the oviduct, the fimbria and the ovary were missing (figure 5); cases in which one uterine horn was missing, but the oviduct and the ovary were present (figure 6); and one case in which the cervix was missing (figure 7). The absence of one uterine horn, the oviduct, the fimbria and the ovary on that side did not prevent females from conceivang in the remaining horn. Several females showing this abnormality were found to be pregnant, although the number of pigs conceived was reduced. The absence of the cervix, of course, prevents conception due to the blockage of the pathway for the sperm.

Blind segments apparently rendered the great majority of females permanently sterile (figure 8). An exception to this was observed in one reproductive tract obtained from a packing house in which one horn was blind at the uterine body while the patent horn contained fetuses. The most common type of blind segments was a blind uterine horn at the junction of the horn and the uterine body. The blind horn was distended at this point by fluid. Since fertilized ova were recovered from the oviducts of the normal horn no explanation can be advanced for the failure of these animals to conceive in the patent normal horn.

A blind uterine body was also observed in a gilt which did not become pregnant.

Unlike the presence of cysts, none of the anatomical abnormalities could be diagnosed prior to autopsy of the female.

Some difficulty was encountered in getting certain females to accept service. There was every indication that intromission was painful and was resented. Occasionally a female permitted apparently normal services during

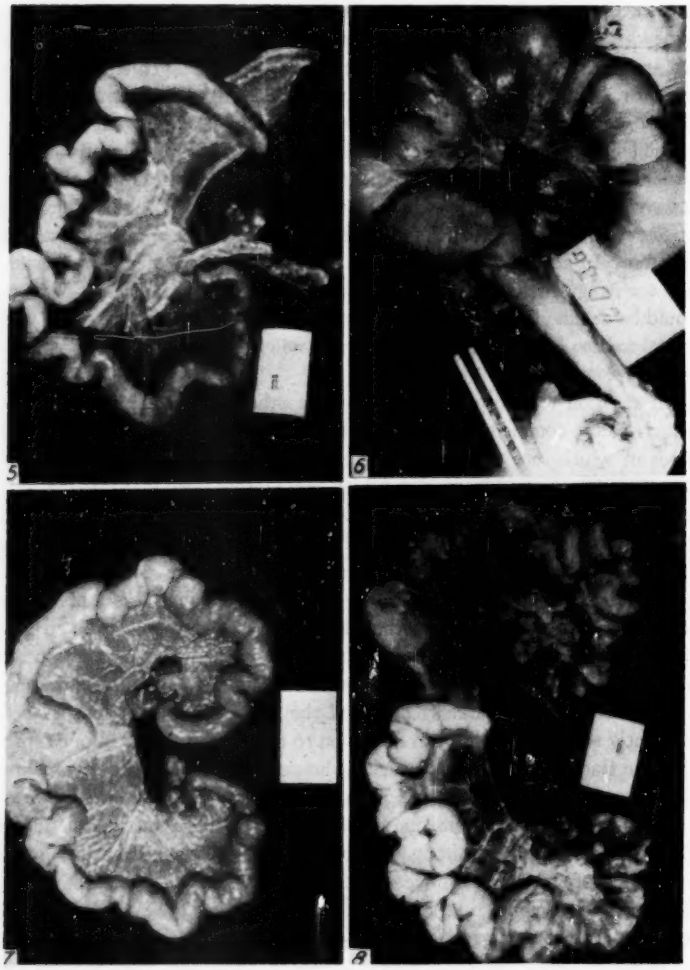

Figure 5. Left non-pregnant horn present, right horn ovary and oviduct missing (packing plant material).

Figure 6. Missing uterine horn, left ovaries and oviducts present, right horn contained 5 fetuses.

Figure 7. Cervix missing.

Figure 8. Both horns present but right horn had no opening into uterine body.

the same heat period during which she would register pain at subsequent services. Upon slaughter the tracts of these females were found to be inflamed in the anterior portion of the vestibule. Cases of ruptured vestibular culs-de-sac, apparently due to penetration by the penis, were observed (figure 4). At the ends of the ruptured culs-de-sac were found bulb-like structures which, when dissected, contained coagulated blood. One case of a ruptured vestibular pocket below the urethral orifice was observed. By watching the actions of such gilts or sows during service this abnormality was suspected in the live animal. However, it did not render a female permanently sterile as fertilized ova or fetuses were recovered from such tracts.

Only one gilt, 354 days of age at autopsy, was found to have infantile reproductive organs and she had shown complete absence of heat periods. At slaughter no corpora lutea or albicantia were found in the ovaries indicating that she had not ovulated. Small follicles were present suggesting that she may have been a late maturing individual. Several females were said not to have shown any signs of heat before being placed on study, but they were all found to be pregnant and must have conceived prior to being placed on experiment.

In about 50% of the females studied, sterility was obviously due to anatomical or endocrine aberrations of the reproductive system. The other half of the females which were culled by the breeders as "sterile," conceived on experiment. It is thought that these latter cases represent "hard-to-settle" females although no definite explanation can be offered for the breeders' failure and our success in inducing them to settle as rapidly as they did. One important difference in management lies in the fact that on experiment these females were bred on an average 3.9 times per heat while the producers bred them on the average 1.4 times during a heat period. Certain preliminary observations indicated that these females may have been abnormally early ovulators; thus a single breeding would tend to diminish the chance of fertilization while more frequent services would increase the chances of the presence of viable sperm at the time when the eggs were ovulated.

In females which showed no abnormalities and which were pregnant, the discrepancy between the number of corpora lutea and the number of fetuses present, indicated that 25.8% of the eggs were either not fertilized or failed to develop into embryos.

Thirty-eight of the 44 females which became pregnant did so during the first heat on experiment and none of them returned into heat, indicating that there was no complete embryonic mortality up to the time when they were killed (table 1). Four other females (5.1%) failed to become pregnant and no causes for their infertility could be established. In one of these

females evidences of resorption were definitely found, embryonic death being due to failure of the corpora lutea. An additional four females required two services on the experiment before they settled suggesting that they may have conceived and resorbed after the first service (table 1). Thus, at most 10% of our females and more likely only 5.1% could be considered to have exhibited any evidence of what might be termed habitual abortion or complete and recurring embryonic mortality. In the remaining cases anatomical or physiological reasons existed for impaired fertility

Summary

Ninety-five gilts and sows which had shown impaired fertility were obtained in 1948 and 1949 from Illinois swine producers and from the University of Illinois for study. Of these, 16 were not included in the study for various reasons. Of the remaining 79 females 53.2% conceived on the study but they must still be regarded as being "hard-to-settle." The rest showed various abnormalities which were responsible for their sterility or low fertility. The most important abnormalities were: tubal aberrations, cystic follicles, and blind or missing portions of the reproductive system. Very little evidence of complete embryonic mortality in individual females was obtained in this sample. The difference between the number of corpora lutea and the number of fetuses indicated that about 26% of the ovulated eggs did not develop into embryos.

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THE NATURE OF REPRODUCTIVE FAILURES IN REPEAT-BREEDER SOWS[1]

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APPROXIMATELY one-fifth of breeding sows fail to conceive when mated. Phillips and Zeller (1941) in a study of the Beltsville herd found that 21.9 percent of the sows during a 12-year period failed to conceive during a breeding season and 36.4 percent of all matings were infertile. In a similar survey of the records from the University of Wisconsin herd (unpublished), it was found that 20.8 percent of the sows failed to conceive and 29.7 percent of all matings were infertile. These losses seem large enough to justify an inquiry into the nature of the reproductive failures which appear to be widespread in occurrence.

The present study is concerned with gilts (nonparous) and sows (parous females) that have been bred at several successive heat periods without conceiving—"repeat breeders." Data were obtained on fertilization, embryonic death, and conditions of the genital organs in these animals of low fertility. Preliminary reports of this study were made by Warnick, Grummer and Casida (1947; 1948). Also, Wilson, Nalbandov and Krider (1948) made a preliminary report of a similar study.

Materials and Methods

Gilts and sows that had been bred at 2 to 4 different heat periods without conceiving (records furnished by owners) were obtained from farms scattered throughout Wisconsin. These animals were checked daily for heat and were bred to fertile boars at their first heat after being admitted to the experimental barn. Most of them were mated to 2 different boars at an interval of 12 to 24 hours. Thirty-seven Poland China, 12 Chester White, 7 Duroc, 4 Berkshire, and 3 Hampshire females were included in the observations. Thirty-one animals were studied in the interval from December 26, 1946, to May 15, 1947, and 32 from January 10 to March 30, 1948.

Part of the animals (group 1) was bred and killed 4 days later to determine the percentage with fertilized eggs; the remainder (group 2) was retained after breeding and the percentage with normal embryos determined at 25 days. Alternate animals were assigned to these 2 groups. The percentage of animals in group 2 with embryos judged to be normal by their gross appear-

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ance was determined at slaughter. Animals not having normal embryos included those with no embryos and those with retarded or degenerating embryos. Also, they included those that returned in heat before 25 days. These latter animals of group 2 were rebred and killed 4 days later as additional animals to determine the percentage with fertilized eggs. Embryonic death was calculated from the difference between the percentages of animals at 4 days with fertilized eggs and of those at 25 days with normal embryos.

Blood samples were collected at the time of slaughter and agglutination tests for brucellosis were made.[2] The genital organs were taken to the laboratory for examination soon after slaughter. The oviducts and upper part of the uterine horns from animals killed 4 days after breeding were flushed with physiological saline solution (0.85% NaCl). The washings were collected in watch glasses for examination of eggs and embryos under the binocular microscope. The embryos, if present in animals killed 25 days after breeding, were examined grossly for normality. Follicles, corpora lutea, and corpora albicantia were measured and counted. Gross examinations were made of the entire genital tract to determine and locate any abnormalities.

TABLE 1. CONDITIONS OF THE GENITAL TRACT ASSOCIATED WITH REPEAT-BREEDER GILTS AND SOWS

Condition of organs	Gilts		Sows	
	Number	%	Number	%
No gross abnormalities present	16	36.3	13	68.4
Gross abnormalities present:				
Fertilization possible—	6	13.7	3	15.8
Unilateral missing segment	(5)	(11.4)	(0)	(0.0)
Cystic follicles plus corpora lutea	(1)	(2.3)	(3)	(15.8)
Fertilization unlikely—	22	50.0	3	15.8
Bilateral tubal abnormalities	(19)	(43.2)	(2)	(10.5)
Bilateral missing segments	(2)	(4.5)	(0)	(0.0)
Bilateral cystic follicles	(1)	(2.3)	(1)	(5.3)
Total	44	100.0	19	100.0

Results and Discussion

Genital abnormalities

Gross abnormalities were present in 63.7 percent of the gilts and 31.6 percent of the sows (table 1). Of these abnormalities, unilateral abnormalities (figure 1) were present in 13.7 percent of the gilts and 15.8 percent of the

[2] Tests made by Veterinary Science Department.

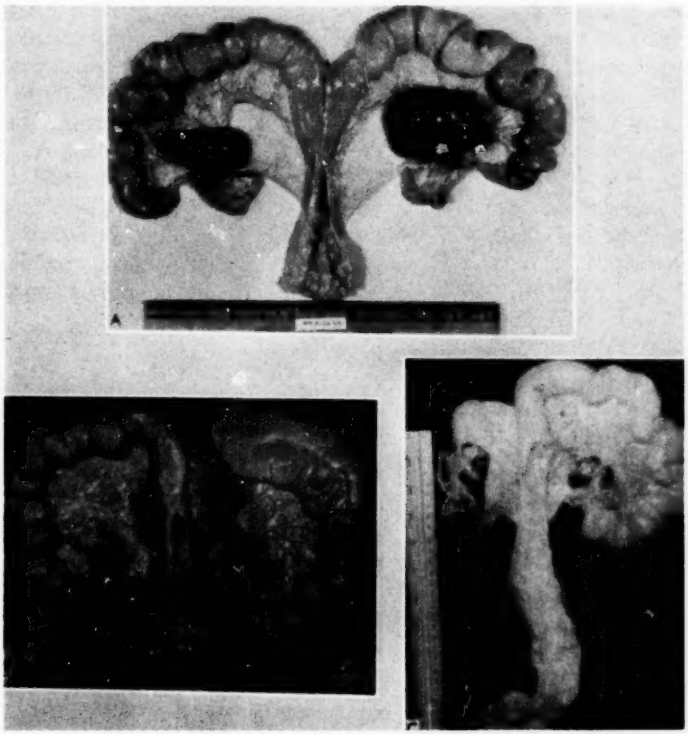

Figure 1. Unilateral genital abnormalities.
A. Cystic follicles plus corpus luteum.
B. Missing segment of uterine horn.
C. Missing uterine horn.

sows, and in them fertilization was not possible on the one side due either to a missing segment of the uterus or to cystic follicles in the ovary. However, in all instances of missing segments, embryos were recovered from the normal side. Bilateral genital abnormalities (figure 2) were for the most part tubal in location and consisted of hydrosalpinx, pyosalpinx, or bursitis. In the first of these there appeared to be an obstruction in the lumen of the oviduct about two-thirds of the distance from the ovary to the uterine horn which caused the accumulation of fluid. Bursitis was associated with most of the cases of hydrosalpinx. In some instances the oviducts were not noticeably distended and the passageways apparently were not closed; purulent ma-

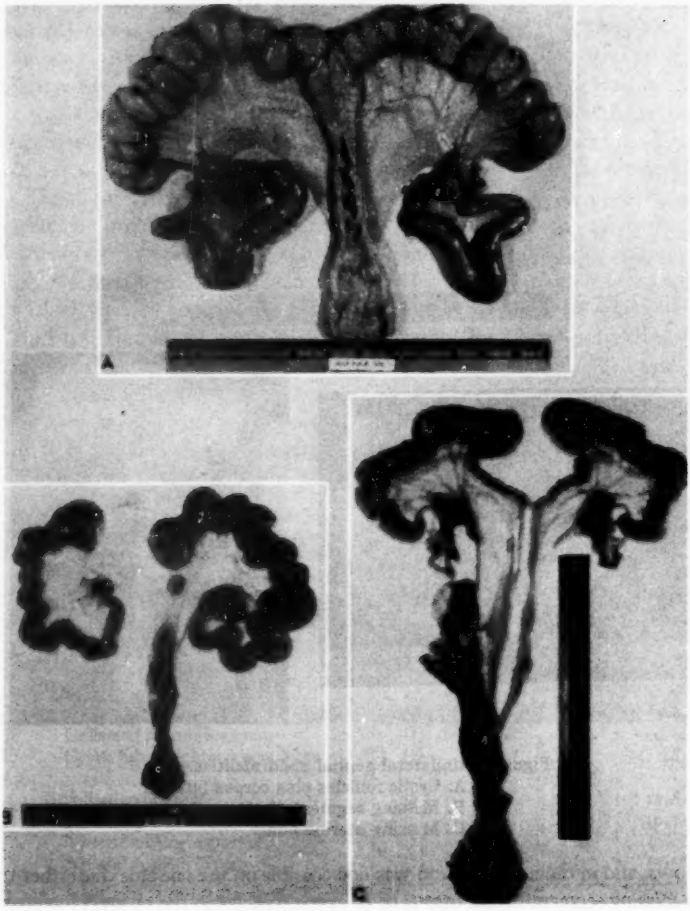

Figure 2. Bilateral genital abnormalities.
A. Bilateral hydrosalpinx.
B. Missing vagina, cervix, and uterine body plus rudimentary male ducts.
C. Missing vagina, cervix, and uterine body plus rudimentary male ducts.

terial, however, was forced out when the tubes were flushed with saline solution (pyosalpinx). The abnormalities in 2 of the gilts were not tubal in location; in them the vagina, cervix, and uterine body were missing (figures 2B, C). Structures were present in the broad ligament which appeared to be rudimentary male ducts.

A significant difference existed between sows and gilts in the incidence of bilateral abnormalities; 50 percent of the gilts and 15.8 percent of the sows (table 2). Many of these abnormalities thus would appear to be present at puberty, which is contrary to the condition in unbred heifers, where it is assumed that they have had little chance of developing tubal abnormalities, Rowson (1942).

TABLE 2. OCCURRENCE OF BILATERAL GENITAL ABNORMALITIES IN GILTS AND SOWS

Parity	1947		1948		Total	
	Number	% abnormal	Number	% abnormal	Number	% abnormal
Gilts	25	32.0	19	78.4	44	50.0
Sows	6	0	13	23.1	19	15.8

The brucella agglutination test made on blood from 59 animals disclosed that 39 percent reacted as positive (agglutination at dilutions of 1:25 and higher) and 61 percent as negative. There was no significant difference in the percentage of reactors between gilts (40.5) and sows (35.3). Of the positive animals, 34.8 percent had bilateral genital abnormalities while 47.2 percent of the negative animals had bilateral abnormalities, a difference that was not statistically significant. Thus, the data fail to give evidence that these abnormalities arise as a result of brucellosis infection.

Fertilization and embryonic death in animals with no genital abnormalities

Considering only the animals with no bilateral abnormalities a comparison of fertility at 4 and 25 days gives data on embryonic death rate (table 3). The percentages of gilts and sows having fertilized eggs at 4 days were 93.3 and 80.0 respectively. Four-day animals include all females of group 1 and also those of group 2 that returned in heat and were rebred. There was no significant difference between the fertilization rates of the 4-day animals from these 2 sources so pooling them seems justified. The percentages of animals with normal embryos at 25 days were 45.4 in gilts and 0.0 in sows. The difference between the 4- and 25-day figure can be converted into an estimate of embryonic death by calculating the percentage that it is of the

4-day figure. Thus, for gilts this would be: $\frac{93.3-45.4}{93.3}\times 100 = 51.3$.

The embryonic death rate in the sows was markedly higher than that in the gilts (100 vs. 51.3, table 3).

TABLE 3. COMPARISON OF FERTILITY BETWEEN GILTS AND SOWS WITH NO BILATERAL ABNORMALITIES

Parity	4 days		25 days		% embryonic death
	Number	% fertile	Number	% fertile	
Gilts	15	93.3	11	45.4	51.3
Sows	15	80.0	8	0	100.0

A comparison of fertilities between negative and positive animals (table 4) indicated that the percentages of animals with fertilized eggs at 4 days were 75 in the former and 100 in the latter (not significantly different). However, the percentages with normal embryos at 25 days were 40 in the negative and 12.5 in the positive group. Consequently, the percentage of embryonic death is much higher in the positive than negative animals (87.5 vs. 46.5). The percentages of positive reactors in gilts and in sows were 35.8 and 40.5 respectively; thus it would appear that there is no association between age and brucellosis infection. These data would seem to indicate that brucella infection, independent of parity, is one of the factors affecting embryonic death.

TABLE 4. COMPARISON OF FERTILITY BETWEEN NEGATIVE AND POSITIVE BRUCELLA REACTOR ANIMALS WITH NO BILATERAL ABNORMALITIES

Brucella reaction	4 days		25 days		% embryonic death
	Number	% fertile	Number	% fertile	
Negative	16	75.0	10	40.0	46.5
Positive	12	100.0	8	12.5	87.5

Incidence of failure of fertilization in all animals

Considering all of the gilts and sows, each studied as a separate population, a division may be made of each into 3 main categories on the basis of reproductive performance during the first 25 days after breeding (table 5). Failure of fertilization accounted for 53.4 percent of the gilts and 32.6 per-

cent of the sows. These percentages were further subdivided into accountable and unaccountable as based on the condition of the genital organs. The percentages of accountable failure of fertilization, 50.0 and 15.8, are shown in table 2. Failure of fertilization in normal animals (unaccountable on the basis of genital abnormalities, table 3) would be 100 minus 93.3 percent or 6.7 percent for gilts and 100 minus 80.0 or 20.0 percent for sows. Normal gilts, however, represent only 100 minus 50.0 or 50.0 percent (from table 2) of the whole gilt population, and normal sows 100 minus 15.8 or 84.2 percent of the whole sow population. Unaccountable failure of fertilization in the whole group of gilts would then be 6.7 percent of 50.0 percent or 3.4 percent and in the whole group of sows, 20.0 percent of 84.2 percent or 16.8 percent.

TABLE 5. NATURE OF REPRODUCTIVE FAILURES IN REPEAT-BREEDER GILTS AND SOWS

	Gilts	Sows
	%	%
Animals repeat because of failure of fertilization	53.4	32.6
Accountable—Gross barriers present	(50.0)	(15.8)
Unaccountable—No gross barriers present	(3.4)	(16.8)
Animals repeat because of embryonic death	23.9	67.4
Animals with normal embryos at 25 days	22.7	0.0
Total	100.0	100.0

Embryonic death in all animals studied

Embryonic death in the 2 separate populations accounted for 23.9 percent of the gilts and 67.4 percent of the sows (table 5). Similar to the calculation above, normal gilts represent only 50.0 percent (table 2) of the whole population, thus, the fertility at 4 days in gilts as a whole is 50.0 percent of 93.3 percent (table 3) or 46.6 percent. The percentage of the gilts as a whole with normal embryos at 25 days is 50.0 percent of 45.4 percent (table 3) or 22.7 percent. Embryonic death in the entire group of gilts is then 46.6 minus 22.7 or 23.9 percent. Normal sows make up 84.2 percent (table 2) of the whole sow population. Thus, the percentage of them pregnant at 4 days is 84.2 percent of 80 percent (table 3) or 67.4 percent. None of the sows had normal embryos at 25 days so the percentage of the whole sow population normally pregnant at this stage would be 84.2 percent of 0 percent or 0 percent. Thus, the embryonic death rate in sows as a whole is then 67.4 minus 0 or 67.4 percent. As was indicated in the above calculations, 22.7 percent of the gilt population and 0 percent of the sow population had normal embryos 25 days after breeding.

Discussion

It would appear that in gilts the presence of bilateral genital abnormalities, which prevented fertilization, was the main cause of repeat breeding. The specific cause or causes for the high incidence of gross bilateral abnormalities is not clear from this study. However, these data suggest that many of the abnormalities are probably present at the time of puberty, which would rule out development during pregnancy or subsequent parturition. Brucellosis infection did not appear to have any influence on the incidence of these bilateral abnormalities. Cultures made of the fluid from the oviducts at the time of slaughter did not show active pathogens.[3]

A comparison of these data can be made with similar study of repeat-breeder cows by Tanabe and Casida (1949). Their study included only cows that had one or more calvings and which had no palpable abnormalities. Thus, their data would be more comparable to the sows than to the gilts. Failure of fertilization was 39.7 percent in cows while it was 32.6 percent in sows. The percentage of failure of fertilization caused by physical barriers was greater in sows than cows (16.8% vs. 8.7%). However, the percentage of failure of fertilization where physical barriers were absent was greater in cows than in sows (31.0% vs. 16.8%). The embryonic death rate was 39.2 percent in cows 34 days after breeding, while it was 64.7 percent in sows 25 days after breeding. None of the sows had normal embryos at 25 days whereas 21.1 percent of the cows had normal embryos at 34 days. Failure of fertilization was higher in gilts than cows (53.4% vs. 39.6%). This difference was due primarily to the high incidence of physical barriers in gilts (50%) compared to cows (8.7%). The embryonic death rate was 39.2 percent in cows before 34 days compared to 23.9% percent in gilts before 25 days. There was close agreement between the percentages of cows (21.1%) with normal embryos at 34 days and gilts (22.7%) with normal embryos at 25 days.

Embryonic death before 25 days after breeding apparently is the major cause of repeat-breeding in sows (67.4%). These data show that embryonic death was nearly 3 times as great a factor in the parous as in nonparous females (67.4% vs. 23.9%). Another possible factor, besides parity, associated with embryonic death would appear to be brucellosis infection. The percentage embryonic death in infected animals was 87.5 compared to 46.5 in noninfected animals, and this difference appears to be independent of the effect of parity. That brucellosis may be a factor in lowered fertility of the breeding herd was shown by Hutchings *et al.* (1946). In their study 8

[3]Cultures made by Dr. S. H. McNutt, Department of Veterinary Science.

naturally infected sows farrowed only 14 litters in a 2-year period, though bred repeatedly to farrow 2 litters per year.

The low percentage of all repeat-breeder animals with normal embryos at 25 days indicates the small chance for such animals to conceive with an additional breeding after they have been bred at 2 to 4 different heat periods without conceiving. The chances of such gilts having normal embryos 25 days after an additional service is approximately 1 out of 4, while the chances of sows having normal embryos 25 days after breeding are practically zero.

Summary

Data are presented on 63 females that had been bred at 2 to 4 different heat periods without conceiving. Repeat breeding was due to a failure of fertilization in 53.4 percent of the gilts and 32.6 percent of the sows. Accountable failure of fertilization due to bilateral tubal abnormalities, bilateral missing segments, or bilateral cystic follicles comprised 50.0 percent of the gilts and 15.8 percent of the sows. Unaccountable failure of fertilization (no gross barriers present) made up 3.4 percent of the gilts and 16.8 percent of the sows. Embryonic death was responsible for repeat breeding in 23.9 percent of the gilts and 67.4 percent of the sows. Thus, the major cause of repeat breeding in gilts appeared to be a failure of fertilization due to genital abnormalities, while in sows it was primarily because of embryonic death. Animals with normal embryos 25 days after one additional breeding included 22.7 percent of the gilts and none of the sows.

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THE EFFECT OF STILBESTROL AND TESTOSTERONE ON THE GROWTH AND FATTENING OF LAMBS[1]

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THE importance of the endocrine system in the regulation of growth has long been known. Only in recent years, however, have hormones, and chemicals which influence hormone secretion, been available in quantity for large animal investigations. Much of the work which has been done thus far has been concerned with the effects of hypo- and hyperthyroidism on growth and fattening. The effects of thyroidectomy in cattle (Andrews and Bullard, 1940, 1943), and of thiouracil and thiourea in cattle (Beeson *et al.*, 1947), in sheep (Andrews *et al.*, 1947), in swine (Muhrer and Hogan, 1945) and in chickens (Andrews *et al.*, 1946) have been reported. The experimental production of hyperthyroidism with thyroprotein and its apparently beneficial effects on growth in swine have been published (Reineke *et al.*, 1948 and Beeson *et al.*, 1949).

The injection of stilbestrol and other estrogens or the implantation of hormone pellets has been shown to improve carcass quality markedly and to increase fat deposition in chickens (Lorenz, 1943, 1945). Andrews and Bohren (1947) found that stilbestrol increased the efficiency of conversion of feed energy to edible carcass calories as much as 75 percent in chickens. Stilbestrol produces a marked lipemia in birds and this apparently results in increased tissue fat deposition. Dinusson *et al.* (1949) reported that the implantation of four 12-milligram stilbestrol pellets increased the rate of gain of fattening heifers and that the implantation of 50 milligrams of testosterone in pellet form affected behavior but had no consistent effect on rate of gain. There was no significant change in blood fat in cattle and it appeared that the increased growth rate was the result of muscular and skeletal development.

Materials and Methods

Blackface wether feeder lambs (Hampshire rams × range ewes) from Montana averaging 71 pounds in weight were used in this experiment. Ten lots of 10 lambs each were fed in duplicate on five different treatments from

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[2] The authors express their appreciation to Wick and Fry, Inc. for the stilbestrol and to Dr. F. E. Houghton and Ciba Pharmaceutical Products, Inc. for the testosterone used in this experiment.

November 17, 1948 until January 26, 1949, a period of 68 days. The lambs were allotted equally according to type, weight and general thriftiness. It should be especially noted that only wether lambs were used. All lots received a basal ration composed of shelled yellow corn, soybean oilmeal, clover-timothy hay and iodized salt. The lambs were fed in an open shed and had free access to hay and water at all times. The concentrate (shell corn and soybean meal) intake of all lots was kept at the same level except on one occasion, a week before the experiment ended, when the control lambs went off feed. Lambs treated with stilbestrol and testosterone had keener appetites, and if allowed would have consumed more concentrate. No attempt was made to control the hay intake of the lambs.

The following experimental treatments were employed: Group I, basal ration, Group II, basal ration plus 12 mg. of stilbestrol, Group III, basal ration plus 24 mg. of stilbestrol, Group IV, basal ration plus 10 mg. of testosterone, Group V, basal ration plus 10 mg. of testosterone at the beginning and another 10 mg. 43 days later The stilbestrol and testosterone were implanted subcutaneously in pellet form in the shoulder region at the beginning of the experiment; and in Group V the lambs received a second treatment 43 days later.

The lambs were weighed individually at the beginning and close of the experiment and at 14-day intervals during the trial. Live grades and market values were estimated on each lot just prior to marketing by two experienced sheep buyers. Individual dressed weights and federal grades were obtained at the time of slaughter.

The data on growth rate and feed efficiency were analyzed statistically by the method of analysis of variance (Snedecor, 1946).

Results and Discussion

Growth Rate

The effects of stilbestrol and testosterone on growth are summarized in table 1. Although the control lambs made excellent gains, 0.35 pound per lamb daily for 68 days, the subcutaneous implantation of either 12 or 24 mg. of stilbestrol in pellet form resulted in highly significant increased gains. It is generally believed that gains of fattening lambs in dry lot in excess of 0.4 pound daily are very apt to be accompanied by enterotoxemia (overeating or pulpy kidney disease). No evidences of these disturbances were observed. One lamb was removed from the 12 mg. stilbestrol group for prolapse of the rectum and a lamb in one of the 24 mg. stilbestrol lots was removed because of a severe bruise and inflammation of the abdominal wall posterior to the sheath. Post-mortem examination revealed no involvement of the bladder or kidneys. The average daily gains for the stilbestrol lambs were

0.49 and 0.50 pound, respectively. The lambs in Group IV, which received one 10 mg. pellet of testosterone propionate at the beginning of the experiment, gained 0.43 pound per day; this was significantly more than the controls ($P < 0.05$). The lambs in Group V were each given a 10 mg. pellet of testosterone at the beginning of the trial and again at 43 days. Although they gained at the rate of 0.41 pound per day, this was not significantly more than the gain of the control lambs. No measurements of skeletal growth were made.

The data on carcass grades suggest that the lambs which received stilbestrol were characterized by somewhat less finish and more growth than the controls and that the lambs which received testosterone were fatter and less growthy than the stilbestrol groups. Dinusson *et al.* (1949) observed that stilbestrol had similar effects in cattle. Andrews and Bohren (1947) found that in chickens stilbestrol results in highly significant increases in

TABLE 1. EFFECT OF STILBESTROL AND TESTOSTERONE ON THE GROWTH RATE, FEED CONSUMPTION AND FEED EFFICIENCY OF LAMBS
(Feeding period, 68 days)

Item		Group number and treatment				
		I Control	II 12 mg. stilbestrol	III 24 mg. stilbestrol	IV 10 mg. testosterone	V 20 mg. testosterone
Number of lambs		20	19[1]	19[2]	20	20
Growth rate (lb.)						
Av. initial wt.	lb.	71	71	72	72	71
Av. final wt.	lb.	95	104	106	101	99
Gain per lamb	lb.	24	33	34	29	28
Daily gain per lamb	lb.	.35	.49**	.50**	.43*	.41
Daily feed consumption per lamb (lb.)						
Shelled corn	lb.	1.11	1.11	1.12	1.12	1.12
Soybean oil meal	lb.	.18	.18	.18	.18	.18
Clover-timothy hay	lb.	3.33	3.40	3.37	3.29	3.35
Salt	lb.	.02	.02	.02	.02	.02
Total	lb.	4.64	4.71	4.69	4.61	4.67
Feed per pound of gain (lb.)						
Shelled corn	lb.	3.20	2.28	2.21	2.60	2.72
Soybean oil meal	lb.	.52	.37	.36	.42	.44
Clover-timothy hay	lb.	9.60	6.94	6.68	7.68	8.17
Salt	lb.	.05	.04	.04	.05	.05
Total	lb.	13.37	9.63**	9.29**	10.76**	11.38*

[1] Lamb No. 87 was removed on account of prolapsed rectum.
[2] Lamb No. 113 was removed due to rupture.
* Difference was significant ($P < 0.05$) over controls (Group I).
** Difference was highly significant ($P < 0.01$) over controls (Group I).

TABLE 2. EFFECT OF STILBESTROL AND TESTOSTERONE ON CARCASS YIELD AND CARCASS GRADES OF LAMBS

Item	Group number and treatment				
	I Control	II 12 mg. stilbestrol	III 24 mg. stilbestrol	IV 10 mg. testosterone	V 20 mg. testosterone
Yield, in percent	46.2	45.3	44.3	45.4	45.6
Carcass grades, in percent					
U. S. Good	55	16	21	65	70
U. S. Commercial	45	79	68	35	30
U. S. Utility	0	5	11	0	0

tissue fat deposition. However, in birds, stilbestrol and other estrogens produce marked lipemia. This did not occur in cattle in the Purdue experiments.

Feed Consumption and Efficiency

The total daily feed consumption was similar for all lots, During the entire experiment the grain intake of all groups was purposely held constant except for one occasion, in the last week of the experiment, when the control groups went off feed. It is believed that the lambs receiving stilbestrol would have consumed more corn if an opportunity had been provided. Because the animals were gaining 0.5 pound per day it was thought that increased feed might cause enterotoxemia. Since no feeding difficulties were experienced, no attempt to limit the feed will be made in future experiments. It is interesting to speculate whether fat deposition might have been increased had more corn been fed. Since two lots of 10 lambs each were maintained for each treatment, it was possible to gather some information on feed efficiency. As shown in table 1, all hormone treated groups were significantly more efficient than the controls and for the stilbestrol and 10 mg. testosterone lots the differences were highly significant ($P<0.01$). The groups treated with stilbestrol required 31 percent less corn per pound of gain. Stilbestrol had similar effects in heifers (Dinusson *et al.*, 1949). Andrews and Bohren (1947) did not find any differences in gross feed efficiency in chickens but when the caloric composition of the edible carcass was compared with the caloric feed intake it was shown that stilbestrol increased caloric efficiency over 75 percent.

Carcass Studies

An analysis of the data showed no significant differences in dressing percent (table 2). However, dressing percent was slightly lower in the groups which received stilbestrol and the carcass grades were not as high as in

either the controls or testosterone treated groups. The present methods of live and carcass grading are not objective enough to lend themselves to detailed analysis. Independent sheep marketing specialists who examined the lambs expressed the opinion that the lambs which received testosterone had the most desirable market finish and a slightly greater live market value. This opinion appears to be borne out by the U.S. carcass grades. As previously discussed, true growth appeared to have been stimulated by stilbestrol. Subsequent experiments have been planned in which attempts will be made to speed fattening by increasing feed intake and to determine at what weights stilbestrol lambs will have degrees of finish comparable to control or testosterone treated animals.

Summary

Subcutaneous implantation of 12 or 24 mg. of stilbestrol or 10 mg. of testosterone significantly increased the gains of wether lambs during a 68-day feeding period.

All hormone treated groups required significantly less feed per pound of gain than the control lambs.

Carcass quality and market value appeared to be improved by the administration of testosterone.

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INFLUENCE OF ESTROGEN ALONE AND IN CONJUNCTION WITH PREGNANT MARE SERUM IN ANESTROUS EWES[1,2]

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Introduction

IN recent years there has been considerable interest in the possibility of hormonally stimulating estrus, ovulation, and lambing in the anestrous ewe. Since the injection of estrogen will stimulate ovarian activity in the rat, it was thought possible that a similar response might be obtained in the ewe. August (1941) reported that injection of 1.0 to 1.5 mg. of estradiol benzoate into ewes induced estrus; more than 4,000 animals treated, 72.5 percent mated and 43.1 percent lambed. An analysis of August's paper shows that 36.5 percent, and not 43.1 percent, of the injected ewes lambed. In determining the percentage of ewes lambing August apparently ignored the flocks in which no lambs were born. The injections, moreover, were made at a time when mating was still occurring in nontreated ewes. Hammond Jr., Hammond and Parkes (1942) studied the influence of estrogens in anestrous ewes. Three ewes were injected with estradiol benzoate (0.5 to 1.0 mg.) and they came into estrus and ovulated. Twelve ewes were injected with stilbestrol dipropionate (0.25 to 1.0 mg.). Of these 12 ewes, 6 came into estrus and 6 ovulated. In only 3 of the 12 ewes, however, were both estrus and ovulation induced. Of 8 yearling ewes injected with 1,000 to 2,000 rat units of estradiol benzoate, 5 came into estrus but none ovulated (Bell *et al.*, 1941). Hammond, Jr. (1945) reported that 3 of 11 ewes injected with 1 to 5 mg. of stilbestrol ovulated, and 5 to 6 treated with 0.25 to 0.50 mg. of di-n-butyrate ovulated. It was thought that stilbestrol induced ovulation only in sheep which had a fair-sized follicle in the ovary. Cole, Hart and Miller (1945) found that ovarian activity was not stimulated in mature anestrous ewes following the injection of estradiol benzoate.

Bell *et al.* (1941) injected 4 ewes with 100 units of pregnant mare serum (PMS) and 1,000 rat units of estradiol benzoate simultaneoulsy. One of the ewes came into estrus but did not ovulate; two ovulated but ovulation was not accompanied by estrus. Three of 4 ewes that received PMS followed by estradiol benzoate ovulated, and one of these came into estrus 5 days after

[1] Journal Series Paper of the New Jersey Agricultural Experiment Station, The State University of New Jersey, Rutgers University, Departments of Animal and Dairy Husbandry.

[2] Aided by a grant from Ciba Pharmaceutical Products, Inc., Summit, N. J.

the injection of PMS. The fourth one neither came into estrus nor ovulated. Frank and Appleby (1943) found that stilbestrol appeared to have an inhibitory effect on PMS. In 7 of 15 instances ovulation was not induced when these hormones were injected simultaneously. Ovulation, however, occurred in all of 13 ewes that received one or more injections of PMS. Hammond, Jr. (1945) reported that stilbestrol, if given before or too soon after administration of PMS, was capable of inhibiting the induction of ovulation by PMS. Estradiol benzoate, in doses large enough to induce sexual receptivity, given with PMS inhibited ovarian activity (Cole, Hart and Miller, 1945).

PMS supplemented with progesterone appears to be no more effective than PMS alone. Cole, Hart and Miller (1945) found that, of 48 ewes receiving both hormones, 6 came into estrus as compared to 6 of 22 receiving PMS alone.

The work reported in this paper was initiated because of August's encouraging results and because English investigators had rather consistently reported ovulation in anestrous ewes following estrogen treatment.

Materials and Methods

In spring and summer, 1944 through 1947, three-quarter-bred Dorset and purebred Hampshire and Cheviot ewes were injected with various hormones either alone or in combination. PMS (Gonadin[3]) was gonadotrophic hormone employed. Three estrogens were used: estradiol (Ovocylin[4]), estradiol dipropionate (Di-Ovocylin[4]), and the dimethyl ether of hexestrol.[5] Five ewes receivied progesterone (Lutocylin[4]) followed by PMS. Injection procedures for the ewes are given in the various sections under results.

The rams were injected with 500 units of PMS about one week before the ewes were treated. The rams' chests were painted, and ewes with well-marked rumps were recorded as having mated. All ewes were ear-marked; and following treatment, lambing dates were recorded.

Results and Discussion

Estradiol

Four different subcutaneous injections of estradiol were given to a group of 7 anestrous ewes. Two received 1.0 mg. followed 16 days later by a similar treatment. One of these ewes mated and conceived the day after the second injection. Estrus was not induced in two ewes that received 1.0 mg.

[3] Gonadin was generously supplied by Cutter Laboratories, Berkeley, California, through the courtesy of Dr. D. H. Wonder.

[4] Ovocylin, Di-Ovocylin, and Lutocylin were generously supplied by Ciba Pharmaceutical Products, Inc., Summit, N. J., through the courtesy of Dr. E. Oppenheimer.

[5] The dimethyl ether of hexestrol was generously supplied by White Laboratories, Inc., Newark, N. J., through the courtesy of Dr. C. W. Sondern.

each on two successive days. One ewe received 2 mg. and another ewe 6 mg. of estradiol; neither mated. A single injection of 12 mg. into one ewe induced estrus the day after injection, but she did not lamb (table 1).

Estradiol dipropionate

Five ewes were injected subcutaneously with 0.35 mg. of estradiol dipropionate. Three of these ewes mated on the second day after injection and two of the three conceived.

One ewe received 1.0 mg. of estradiol dipropionate and 1.4 mg. 16 days later, since the first injection did not induce estrus. The day after the second injection the ewe mated but she did not lamb. Fourteen ewes were injected with 1.4 mg. of estradiol dipropionate; of these, 11 mated within 4 days after injection, but only one lambed. During the course of injections one non-injected ewe of the flock mated but she did not lamb (table 1).

On August 4, 1945, four grade ewes were injected subcutaneously with 1.4 mg. of estradiol dipropionate. A fifth ewe received no treatment. A ram was placed with the ewes following injection. Ewe No. 4 had mated by 8:30 A.M. on August 6; ewe No. 1 had mated by 8:15 A.M. on August 7; and ewe No. 3 had mated by 4:00 P.M. on August 7. Ewe No. 5 and the control ewe, No. 0, did not mate. Four ewes were slaughtered August 9, and one ewe was slaughtered August 17. Two ewes that were injected and that had mated each had a corpus luteum in one ovary and the uterus appeared to have been stimulated. The third ewe that had mated following injection showed neither corpora lutea nor mature follicles in the ovaries and the uterus was pale, indicating that it had not been stimulated. The remaining injected ewe, which did not come into estrus, had a corpus luteum in one ovary but it was not a recently formed one. This corpus luteum, therefore, was not produced by the injected estrogen. It is possible, however, that the presence of the corpus luteum at the time of injection prevented the induction of estrus. The uterus had not been stimulated. An ovary of the control ewe contained a corpus luteum but the uterus showed no mascroscopic evidence of stimulation.

Dimethyl ether of hexestrol

Nine ewes each received orally 20 mg. of dimethyl ether of hexestrol in a capsule. Nine additional ewes received similar treatment except that a second capsule was given 16 days after the first one. Estrus was not induced in any of these ewes (table 1).

Estrogen and pregnant mare serum

Estradiol dipropionate and pregnant mare serum. Five ewes were injected subcutaneously with 1.4 mg. of estradiol dipropionate and 250 rat units of

TABLE 1. THE INFLUENCE OF ESTROGENS IN ANESTROUS EWES

Ewe No.	Estrogen treatment			Date mated	Date lambed
	Kind*	Quantity—mg.	Date		
	Subcutaneous injection				
2	E	1.0	4/24		
	E	1.0	5/10	5/11	10/3
11	E	1.0	4/24		
	E	1.0	5/10		
90	E	1.0	5/22		
	E	1.0	5/23		
91	E	1.0	5/22		
	E	1.0	5/23		
3	E	2.0	5/3		
5	E	6.0	5/10		
1	E	12.0	5/10	5/11	
11	E-D	0.35	5/25	5/27	10/20
5	E-D	0.35	5/25	5/27	10/23
3	E-D	0.35	5/28		
4	E-D	0.35	5/28		
20	E-D	0.35	6/1	6/3	
23	E-D	1.0	5/3		
	E-D	1.4	5/19	5/20	
11	E-D	1.4	5/29	6/2	
3	E-D	1.4	7/21	7/24	
5	E-D	1.4	7/21		
90	E-D	1.4	7/21	7/24	
91	E-D	1.4	7/21	7/25	
20	E-D	1.4	4/19	4/22	
21	E-D	1.4	4/19	4/21	9/16
22	E-D	1.4	4/24	4/28	
26	E-D	1.4	4/24	4/26	
27	E-D	1.4	5/22	5/24	
28	E-D	1.4	5/22	5/25	
4	E-D	1.4	7/27	7/30	
9	E-D	1.4	7/27		
92	E-D	1.4	7/27		
25			4/26		
	Oral Administration				
9 ewes	DEH	20 0	5/17		
9 ewes	DEH	20.0	4/26		
		20.0	5/12		

* E-estradiol; E-D-estradiol dipropionate; DEH-dimethyl ether of hexestrol.

PMS on the same day. All of the ewes mated on the second day after treatment, but none of them lambed.

Thirteen ewes were injected subcutaneously with 1.0 mg. of estradiol dipropionate. None of the ewes came into estrus, and 16 or 17 days later each ewe was injected subcutaneously with 250 rat units of PMS. Three of the 13 ewes mated and lambed (table 2).

Dimethyl ether of hexestrol and pregnant mare serum. Each of six ewes received 10 mg. of the dimethyl ether of hexestrol mixed in one pound of a grain ration. None of the ewes came into estrus, and 15 days later they were injected subcutaneously with 250 rat units of PMS. Three of the 6 ewes came into estrus, mated, and lambed (table 2).

TABLE 2. INFLUENCE OF OVARIAN HORMONES AND PREGNANT MARE SERUM IN THE ANESTROUS EWE

No. of ewes	Hormone treatment				No. mated	No. lambed
	Kind*	Quantity	Route	Date		
5	E-D	1.4 mg.	Subcutaneous	5/25		
	PMS	250 r.u.	"	5/25	5	0
13	E-D	1.0 mg.	"	5/8		
	PMS	250 r.u.	"	5/25	3	3
6	DEH	10 mg.	Fed	5/8		
	PMS	250 r.u.	Subcutaneous	5/23	3	3
4	P	0.5 mg.	"	5/25		
	PMS	250 r.u.	"	5/26	1	1
1	P	0.5 mg.	"	6/1		
	PMS	250 r.u.	"	6/1	1	0

* E-D—estradiol dipropionate; PMS—pregnant mare serum; DEH—dimethyl ether of hexestrol; P—progesterone.

Progesterone and pregnant mare serum

Four ewes received subcutaneously 0.5 mg. each of progesterone, and on the following day they were injected with 250 rat units of PMS. Eighteen days later one of these ewes mated and conceived. One ewe received simultaneously 0.5 mg. of progesterone and 250 rat units of PMS. This ewe mated two days after treatment, but she did not lamb (table 2).

Discussion

It appears that estradiol dipropionate is more effective in inducing estrus in the anestrous ewe than is estradiol. Although estradiol dipropionate is very effective in inducing mating, such a response is of little practical value,

since only 9 percent of such mated ewes lambed. No evidence was obtained that would indicate that estrogens are effective in initiating the estrous cycle when administered either below or at a level sufficient to induce sexual receptivity.

Although a single injection of PMS is effective in bringing about ovulation in the anestrous ewe, it is not very effective in inducing mating and lambing. In our previous work (Vander Noot, Reece and Skelley, 1946) it was shown that only 12.4 percent of these ewes receiving a single injection of PMS mated. Following a second injection, however, 72 percent mated. The percentage of mated ewes that lambed following a single PMS injection is likewise lower than that following the second injection, 23 and 57 percent respectively. In the present work the simultaneous administration of estrogen and PMS resulted in mating in all cases. None of the ewes lambed, however, probably because of failure to ovulate, since other workers have shown that estrogens are capable of inhibiting the induction of ovulation by PMS. The acdministration of estrogen to 19 ewes, 15 to 17 days prior to an injection of 250 rat units of PMS, resulted in the mating of 6 (32 percent of them). It would seem, therefore, that estrogen treatment 15 to 17 day days prior to a single injection resulted in mating of a higher percentage of ewes than did PMS given alone, 12 and 32 percent, respectively. Likewise the percentage of mated ewes that lamb following estrogen treatment and then a single injection of PMS is higher than that following a single injection of PMS alone, 100 and 23 percent respectively.

Summary

Of 14 ewes injected subcutaneously with 1.4 mg. of estradiol dipropionate, 11 mated within 4 days and one lambed; estradiol was relatively ineffective in inducing estrus. The oral administration of 20 mg. of the dimethyl ether of hexestrol failed to induce estrus. No evidence was obtained that would indicate that estrogen treatment will initiate the estrous cycle in anestrous ewes.

Of 19 ewes receiving estrogen 15 to 17 days prior to a single injection of 250 rat units of PMS, 6 mated and lambed.

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THE EFFECT OF VITAMIN A DEFICIENCY ON SEMEN QUALITY AND THE EFFECT OF TESTOSTERONE AND PREGNANT MARE SERUM ON VITAMIN A DEFICIENT RAMS[1]

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NUMEROUS investigators, including Guilbert and Hart (1935), Hart (1940), Erb *et al.* (1944), Erb *et al.* (1947), Madsen *et al.* (1948), and Hodgson *et al.* (1946) have shown that a vitamin A deficiency causes a lowering of semen quality and production in bulls. In addition to the above investigators, Jones *et al.* (1946) found that a degeneration of the germinal epithelium was associated with a vitamin A deficiency in bulls. Gunn *et al.* (1942) observed seminal degeneration in rams fed carotene deficient rations. The observations by Erb *et al.* (1947), Hodgson *et al.* (1946), Jones *et al.* (1946), and Madsen *et al.* (1942) that pituitaries are often cystic in the vitamin A deficient bovine, has suggested the possibility that vitamin A deficiency may exert its deleterious effect on reproduction indirectly through the anterior pituitary gland. Gunn *et al.* (1942) improved the semen quality of a ram deficient in vitamin A by injections of pregnant mare serum. Hogdson *et al.* (1946) obtained similar results with a vitamin A deficient bull.

The effect of a vitamin A deficiency on rams and the effect of the injection of pregnant mare serum and testosterone propionate on vitamin A deficient rams is reported in this paper. Observations of the addition of ten vitamins of the B-complex to the basal ration are recorded, and the effect of a vitamin A deficiency on the vitamin C content of the blood plasma is noted.

Materials and Methods

Thirty-one Hampshire, two crossbred (Hampshire×Columbia) and two Columbia ram lambs were used in this study. At the beginning of the ex-

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A 350 foot 16 mm. silent-color film describing this experiment can be obtained from the Department of Visual Education at Washington State College, Pullman, Washington.

periment the rams were three to five months of age and varied in weight from 46 to 96 pounds.

The basal ration was composed of natural feedstuffs very low in carotene but was designed to supply ample total digestible nutrients. Composition of the basal ration was as follows:

Wheat straw (ground)	25%
Molasses beet pulp (dried)	25%
Wheat (cracked)	15%
Oats	17%
Linseed oil meal	18%
	100%

Four-tenths (0.4) pound of irradiated yeast (9,000,000 units of vitamin D per pound) was mixed with each ton of feed. Steamed bone meal and iodized salt were fed free choice throughout the experiment. After the fifth month of the experiment, 0.5% of steamed bone meal was mixed in the ration. Wheat straw was not available during the first two weeks of the third month of the experiment, and during that peroid was replaced pound for pound in the ration by dried beet pulp.

The available rams were divided into seven lots of five each. The lots were approximately equal in average initial weight and as comparable in breeding as was possible with the stock available. All lots were hand fed the basal ration to the limit of appetite and six lots received various vitamin and hormone supplements. The testosterone propionate was dissolved in peanut oil and injected subcutaneously in the shoulder region. Pregnant mare serum received by rams in lot V was prepared from the blood of a pregnant mare according to methods outlined by Cole and Saunders (1935), assayed on 21 day old female rats, and injected subcutaneously in the shoulder region. The pregnant mare serum given to the rams in lot VI was prepared by Cutter Laboratories. All vitamins were administered orally in gelatin capsules. The specific treatment of each of lot was as follows:

Lot I—Basal ration plus vitamin A (20,000 I. U. daily) in the form of percomorph liver oil

Lot II—Basal ration.

Lot III—Basal ration plus semi-weekly injections of 12.5 mg. of testosterone propionate throughout the experiment.

Lot IV—Basal ration plus semi-weekly injection of 37.5 mg. of testosterone propionate after vitamin A deficiency symtoms began to appear.

Lot V—Basal ration plus semi-weekly injections of 150 R. U. of pregnant mare serum throughout the experiment.

Lot VI—Basal ration plus semi-weekly injections of 500 R. U. of pregnant mare serum after vitamin A deficiency symptoms appeared.

Lot VII—Basal ration plus vitamin A (20,000 I. U. daily) plus 10 B-complex vitamins as follows (in mg. per kg. body wt. daily): thiamine 0.26, riboflavin 0.06, niacin 0.60, pantothenic acid 0.25, pyridoxine 0.10, choline 5.00. The following vitamins were fed at the following levels per 100 gms. of feed: biotin 5 micrograms, folic acid 25 micrograms, para-aminobenzoic acid 2.5 mg., and inositol 25 mg.

The rams were weighed every two weeks throughout the experiment.

Blood plasma vitamin A and carotene determinations were made each month by the method of Kimble (1939). Hemoglobin content of the blood was determined at the same time by the method of Evelyn (1946). Blood plasma vitamin C was determined by the method of Mindlin and Butler (1938) on two occasions—three and six days before the end of the experiment.

Semen samples were collected once a week by means of an artificial vagina as soon as the rams reached an age when it was possible to make collections. Volume, initial motility, motility after one hour at 37.5° C., methylene blue reduction time, and density were determined for each semen sample according to the methods used by Warwick *et al.* (1948).

Results and Discussions

Vital statistics

Table I gives information regarding death losses, number of semen collections, time of onset of vitamin A deficiency symptoms, and number of rams autopsied. Eight rams died of urinary calculi during the experiment. These losses occurred in both vitamin A deficient and supplemented lots. Vitamin A deficiency has been suggested as a possible cause of urinary calculi formation (Schmidt, 1941, and Pearson *et al.*, 1945), but these data suggest some characteristic of the ration other than its low carotene content as a causative agent.

General symptoms of vitamin A deficiency

Although there was considerable variation in time of onset and severity of symptoms, all rams on the basal ration not supplemented with vitamin A eventually showed definite evidence of vitamin A deficiency. None of the rams in the two lots supplemented with vitamin A showed such symptoms.

About seven weeks after being placed on the deficient ration, a few rams began having attacks characterized by stiffness of the legs, cocking of the head to one side, and inability to stand. Initially these attacks lasted only a few hours after which the affected ram would resume a normal behavior. The duration of the attacks tended to become progressively longer until the

ram eventually became to weak too stand. In some cases rams which were apparently doing well except for partial loss of appetite would suddenly become moribund and some never recovered. In other cases the attacks were less severe with the ram merely becoming listless and failing to eat for a time. Two rams had a slight trembling and occasional mild convulsions possibly

TABLE 1. SUMMARY OF RAM MORTALITY, NUMBER OF SEMEN COLLECTIONS, TIME OF ONSET OF DEFICIENCY SYMPTOMS, AND TIME OF AUTOPSY

Lot No.	I	II	III	IV	V	VI	VII
	(Basal +vit. A)	(Basal)	(Basal +TP[1] throughout experiment)	(Basal +TP after vit. A defic. symptoms developed)	(Basal +PMS[2] throughout experiment)	(Basal +PMS after vit. A. defic. symptoms developed)	(Basal +vit. A+10 B-complex vitamins)
Original no. of rams	5	5	5	5	5	5	5
No. rams died during exp.[3]							
Due to urinary calculi	2 (69)	2 (124)	1 (172)	—	2 (85)	—	1 (88)
Due to other causes	—	1 (117)	1 (199)	1	—	—	2 (162)
Semen collections:							
No. rams prod. samples	2	1	4	3	3	2	3
Total no. samples	30	14	30	24	39	20	40
Vit. A defic. symptoms:							
No. rams showing	0	3[4]	4[4]	5	3[4]	5	0
Av. no. days on experiment when first noted	—	108	151	118	135	143	—
Autopsies:[5]							
No.	3	2	3	5	3	5	2
Av. no. days on experiment when performed	246	246	246	226	246	240	246

[1] Testosterone propionate.

[2] Pregnant mare serum.

[3] Figures in parenthesis refer to average number of days on experiment when death occurred.

[4] Other rams died before vitamin A symptoms developed.

[5] Animals sacrificed at end of experiment or when in advanced stages of vitamin A deficiency or which apparently died of vitamin A deficiency. Does not include routine post mortem examinations of animals dying from other causes during course of experiment.

similar to convulsions observed by Erb *et al.* (1947) in vitamin A deficient bulls.

Most rams on the deficient ration eventually exhibited an uncoordinated gait and progressive weakness which became so severe in some cases that they were unable to stand and had to be fed and watered in shallow pans on the floor. Several animals showed a distinctly swayed back (fig. 2) and some walked on their knees, apparently as a result of loss of control over the lower part of the leg.

The rams were checked for night blindness by placing a panel across a frequently used alley at twilight and checking the rams individually for their ability to avoid it when driven through the alley. All deficient animals were night blind by the twenty-first week of the experiment. One ram showed impaired vision during the day, but at no time was there evidence of xerophthalmia in any animal.

Other symptoms exhibited by the deficient rams included partial loss of appetite, sullenness, and evidence of being in pain.

Considerable variation, presumably due to differences in the amount of stored vitamin A, was observed in the time of onset and severity of deficiency symptoms between rams in the same lot. There was no evidence that injections of either pregnant mare serum or testosterone propionate had any effect on the general deficiency symptoms.

Rate of gain

Analysis of variance indicates that differences between lots in average daily gain (table 2) for the entire period are highly significant ($P < .01$), although, as shown in figure 1, the differences in rate of gain did not become apparent until the experiment had been in progress for several months. During the latter part of the experiment all deficient rams gained at a slower rate than those receiving vitamin A supplementation. Most of the deficient rams eventually lost weight.

The average daily gain of 0.51 pound per day in Lot VII, which received the basal ration supplemented with ten B-complex vitamins, is essentially the same as the average daily gain of 0.49 pound per day made by rams in Lot I receiving only vitamin A as a supplement. Thus, the indication is strong that the basal ration either supplied adequate amounts of these substances or that it permitted normal rumen synthesis.

The average daily gain of 0.27 pound per day by rams on rations not supplemented with vitamin A contrasts sharply with the gains made by the two lots supplemented with vitamin A.

Blood plasma vitamin A and vitamin C

Blood plasma vitamin A was maintained at normal levels in the lots supplemented with vitamin A (table 2), but as shown in figure 1 it dropped to very low levels in the unsupplemented lots. After four and one-half months only traces of the vitamin were found in the deficient rams. This relatively rapid depletion contrasts sharply with the nearly two years and nine months required to deplete aged ewes and ewe lambs, repsectively, in the work of Hart and Miller (1937). It probably resulted from the fact that the rams were young and had been on green pasture for a period not exceeding two months when put on deficient diets.

TABLE 2. AVERAGE DAILY GAIN, AVERAGE BLOOD PLASMA LEVELS OF VITAMINS A AND C, AVERAGE BLOOD HEMOGLOBIN LEVELS, AND AVERAGES OF VARIOUS CRITERIA OF SEMEN QUALITY IN RAMS ON CAROTENE DEFICIENT AND SUPPLEMENTED RATIONS FOR A PERIOD OF 246 DAYS

Lot No.	I	II	III	IV	V	VI	VII
	(Basal+vit. A)	(Basal)	(Basal+TP[1] throughout experiment)	(Basal+TP after vit. A defic. symptoms developed)	(Basal+PMS[2] throughout experiment)	(Basal+PMS after vit. A defic. symptoms developed)	(Basal+vit. A +10 B-complex vitamins)
Av. daily gain (lbs.)[3]	0.49± .10	0.21± .07	0.38± .07	0.20± .08	0.29± .07	0.28± .07	0.51± .09
Plasma vit. A (γ per ml.)[4]	0.31± .02	0.09± .03	0.09± .03	0.09± .03	0.09± .03	0.11± .04	0.29± .02
Av. blood hemoglobin (gms. per 100 ml.)[5]	11.12± .35	11.70± .23	12.06± .07	11.31± .42	11.16± .20	11.36± .21	11.34± .30
Av. plasma vit. C (mg. per 100 ml.)[5]	0.63± .03	0.26± .03	0.35± .04	0.19± .06	0.24± .02	0.21± .03	0.59± .04
Av. volume of semen per collection (ml.)[6]	0.91± .06	0.70± .10	0.82± .06	0.57± .05	0.68± .03	0.74± .07	0.99± .04
Av. initial motility of semen (score)[6]	3.71± .35	2.45± .61	3.24± .40	1.69± .40	0.99± .16	2.85± .47	4.64± .21
Av. motility after 1 hr. at 37.5° C (score)[6]	1.88± .32	1.08± .42	1.40± .35	0.72± .21	0.32± .09	1.35± .32	1.66± .36
Av. time required to reduce methylene blue (min.)[6]	33.6 ± 9.12	57.1 ±15.7	39.3 ±11.9	76.0 ± 9.7	104.8 ± 5.1	41.5 ± 9.8	13.7 ±2.2
Av. semen density[6] (colorimeter readings)	54.2 ± 1.5	57.5 ± 2.2	59.1 ± 1.7	63.7 ± 2.1	63.4 ± 1.3	54.6 ± 1.1	52.3 ±1.2
Av. testicle wt. (gms.)[7]	639.0 ±89.8	239.5 ± 6.8	293.5 ±46.1	203.3 ±14.3	450.0 ±40.0	404.3±61.4	551.0 ±7.9

[1] Testosterone propionate.
[2] Pregnant mare serum.
[3] Averages for entire experiment.
[4] Average values for samples taken at monthly intervals throughout experiment.
[5] Average values for samples taken twice from surviving rams during final week of experiment.
[6] Average values for all semen samples collected.
[7] For rams autopsied at end of experiment or when in advanced stages of vitamin A deficiency or which apparently died of vitamin A deficiency.

Blood plasma vitamin C was determined only near the close of the experiment. At that time plasma vitamin C level averaged less than half as high in the deficient lots as in those supplemented with vitamin A. Considering all rams as a single group there was a positive correlation of .94

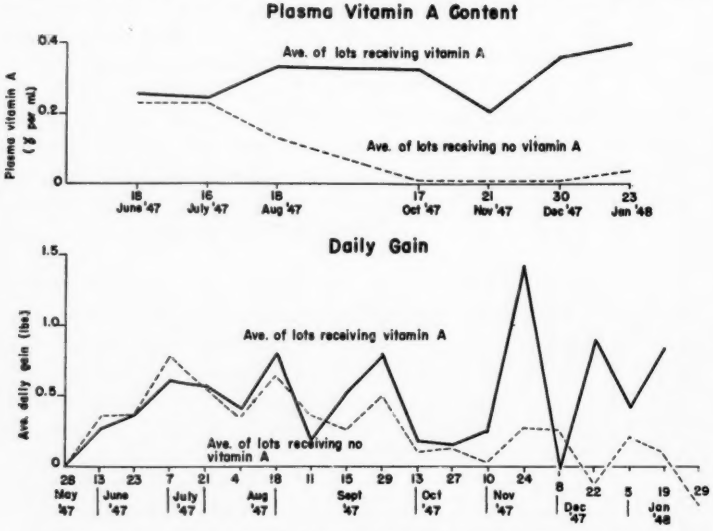

Figure 1. The effect of a vitamin A deficiency on the plasma vitamin A (upper) and rate of gain in ram lambs (lower).

between plasma vitamins A and C. This indicates either an impaired synthesis or an increased need for vitamin C during vitamin A deficiency in the ram. Similar relationships have been observed by Boyer *et al.* (1942) in dairy calves.

Blood homoglobin

Hemoglobin content was maintained at normal levels in all experimental animals, and the small differences in average levels observed between lots (table 2) are not statistically significant. It thus appears that under the conditions of this experiment, vitamin A deficiency, supplementation with ten members of the vitamin B-complex, and injections of testosterone propionate or pregnant mare serum were without effect on blood hemoglobin level.

Semen production and characteristics

The number of rams from which it was possible to collect semen was lower than hoped for because of death losses prior to the age of sexual

maturity and because some rams failed to show enough sex interest and drive to make semen collections with the artificial vagina possible. A total of 200 collections was made from 18 rams (table 1). Five rams in the deficient lots failed to show any evidence of sex interest. Two rams in the supplemented lots lacked the docility necessary for ejaculation into the artificial vagina, but did show some sex interest. Thus the incidence of lack of interest was

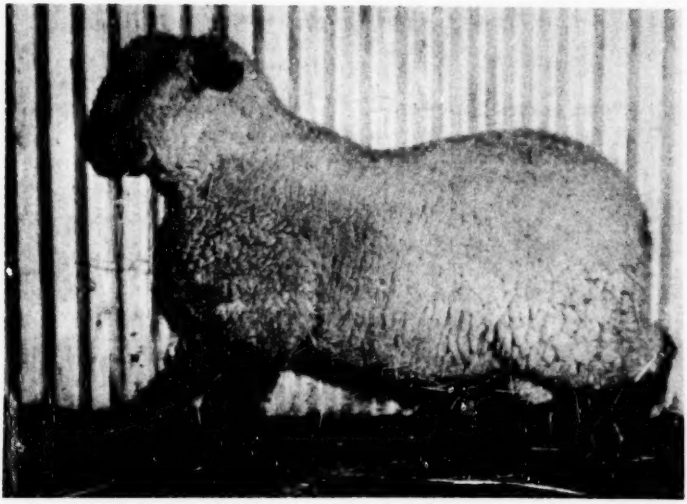

Figure 2. Typical appearance of lambs which did not receive a vitamin A supplement. Note the extreme weakness of the ram.

somewhat higher in the deficient lots and may have been related to vitamin A deficiency. However, the vitamin A deficient rams after ejaculating once maintained sex interest even when too weak to mount a ewe or even to stand. In several instances it was possible to make semen collections from such rams without their mounting normally.

The average figures for the various items used as criteria of semen quality (table 2) over the entire period of collections indicates a definite lowering of semen production and quality by rams on the vitamin A deficient rations. Analysis of variance indicates that the between lot differences are highly significant ($P < .01$) in the cases of semen volume, initial motility, ability to reduce methylene blue, and concentration of spermatozoa. Differences in motility after one hour at 37.5° C. are significant at the 5% level. In agreement with the observations of other workers, a marked increase in per-

centage of morphologically abnormal sperm cells was noted in the vitamin A deficient lots (figure 4).

Differences between vitamin A supplemented lots and the lots on specific treatments were statistically significant in several cases, but in other cases significance could not be established. This is doubtless due to two factors, namely (1) the relatively small number of observations in a given lot, and (2) the variation in the time of onset and severity of deficiency symptoms

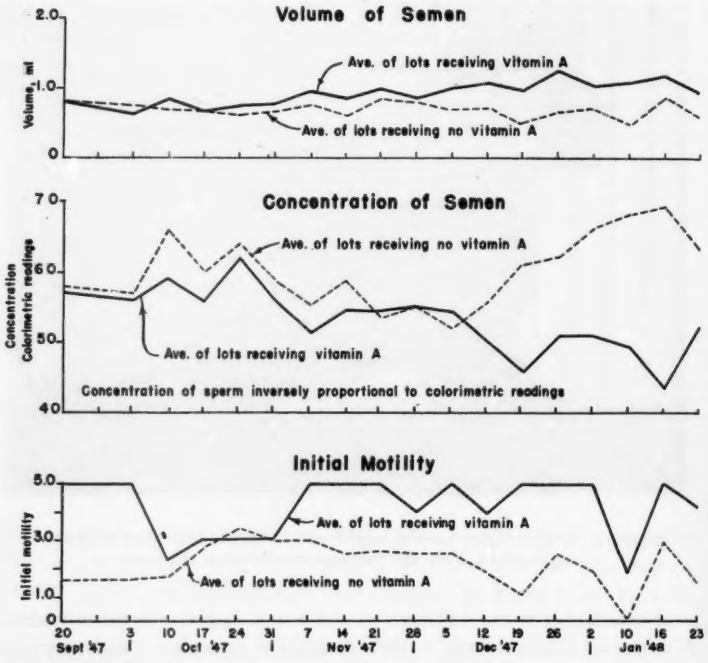

Figure 3. The effect of a vitamin A deficiency on the semen volume (upper), sperm concentration (center), and initial motility (lower), of semen in the ram.

within lots. In all cases, regardless of treatment, rams with severe deficiency symptoms produced semen of low quality. Figure 3 presents graphically the time trends in volume, initial motility, and spermatozoa concentration. These indicate that vitamin A deficient rams in all lots, regardless of hormone treatment, eventually produced semen of low quality. There is, thus, no evidence that either testosterone propionate or pregnant mare serum exerted any beneficial effect on semen production or quality. In several cases physical weakness prevented the vitamin A deficient rams from producing semen.

Comparison of the semen production and quality of Lot I (basal plus

vitamin A) and Lot VII (basal plus vitamin A plus 10 B-complex vitamins) showed statistically significant differences in favor of Lot VII in initial motility and methylene blue reduction time. With the small number of rams there is little basis for judging whether the differences are due to the addition of ten B-complex vitamins or to chance individuality of the rams. Differences in other semen measurements were not significant.

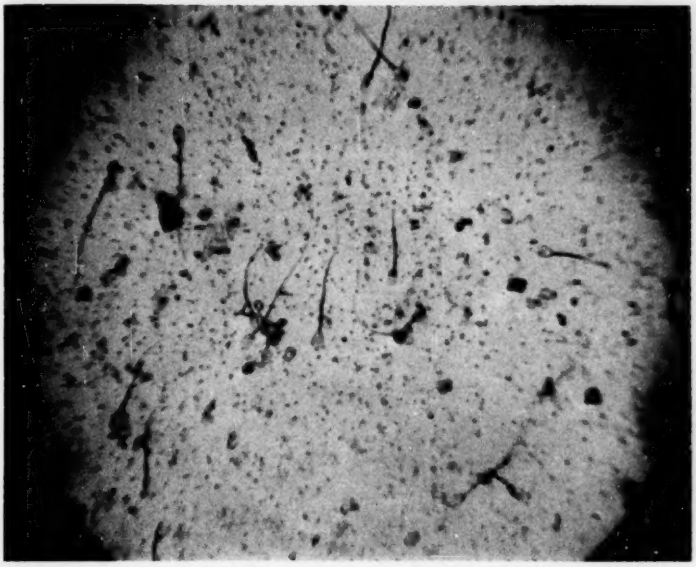

Figure 4. Abnormal sperm caused by a vitamin A deficiency. Note the sperm without tails.

Weight and histological characteristics of testicles and pituitary glands

Testicle weight (table 2) differed significantly between lots for the rams autopsied, averaging 603.8 gms. in rams receiving vitamin A supplementation, 239.5 gms. in rams with no supplement, 239.4 gms. in rams receiving testosterone propionate and 423.8 gms. in rams receiving pregnant mare serum. Pregnant mare serum apparently partially maintained testicle weight while testosterone propionate was without effect in this regard. Histological examination of the testicles failed to reveal which cellular elements were stimulated by pregnant mare serum.

Degeneration of the germinal epithelium was apparent in all except one (a ram from Lot IV) vitamin A deficient ram and in this case the diameter of the seminiferous tubules appeared smaller than normal. The remaining

deficient rams showed a marked disorganization of the germinal epithelium (figure 6). In some cases it was only a few cell layers in height, and in others had sloughed away from the basement membrane. There was evidence of spermatogenesis in only a few scattered areas. Neither testosterone propionate nor pregnant mare serum injections were effective in maintaining testicular structure.

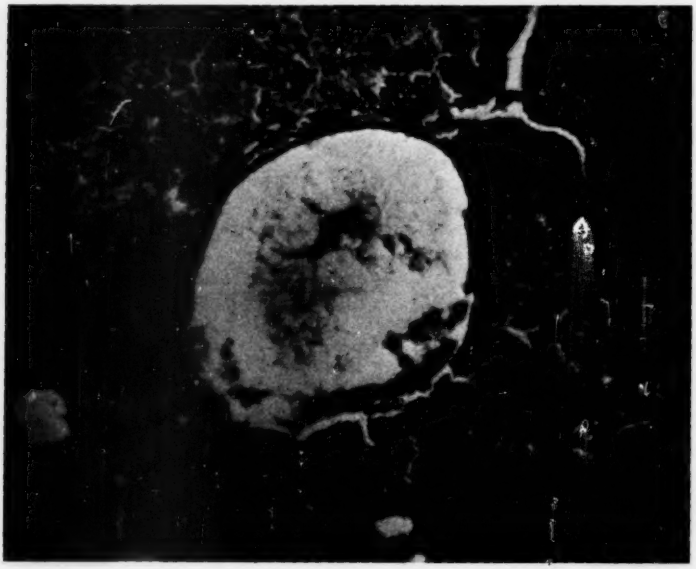

Figure 5. Cystic condition of the pituitary glands associated with the vitamin A deficiency. A high percentage of rams deficient in vitamin A showed this condition.

No gross differences in pituitary gland size or structure between lots were apparent at autopsy. Pituitary gland weights were not taken.

Histological examination of the pituitary glands revealed the presence of small cysts (figure 5) in all except two pituitary glands from deficient rams. None of the glands from rams receiving vitamin A were cystic. The glands from deficient rams not showing cysts were damaged by the fixative so it cannot be definitely stated that they did not contain cysts. Neither testosterone propionate nor pregnant mare serum injections prevented the development of cysts. While considerable variation was observed in the size of cysts, it did not appear to be related to hormone treatment.

The presence of cystic pituitary glands in rams is consistent with the

observations of other workers on vitamin A deficient animals of other species. However, the condition in this experiment was apparently not as severe as reported by Wolback and Howe (1925) in rats or by Erb *et. al.* (1947), Hodgson *et al.* (1946), Jones *et al.* (1946), and Madsen *et al.* (1942) in cattle.

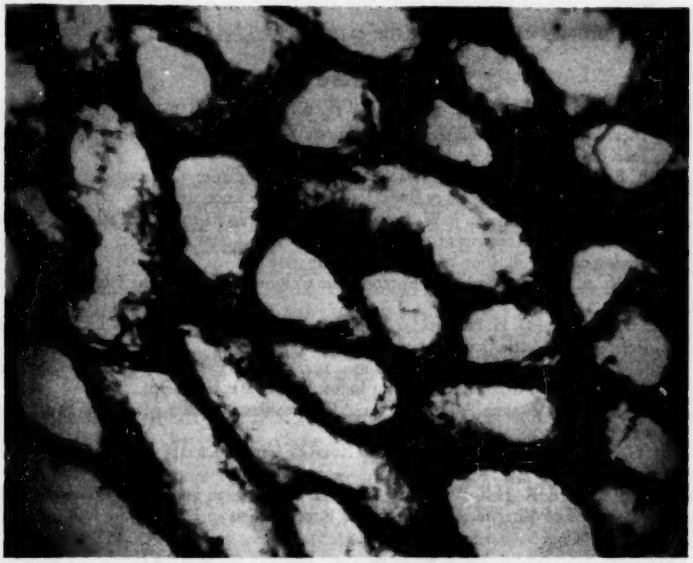

Figure 6. Degeneration of the germinal epithelium in rams deficient in vitamin A. Note the almost complete absence of germinal layers.

Summary

Thirty-five Hampshire and Columbia ram lambs were put on experiment at three to five months of age and fed natural rations almost devoid of carotene supplemented in various lots with (1) vitamin A, (2) ten members of the vitamin B-complex, (3) testosterone propionate, or (4) pregnant mare serum.

Vitamin A supplementation resulted in normal growth, normal blood vitamin A and C levels, and the production of normal semen, The effects of other supplements were negligible. Rams on rations not supplemented with vitamin A developed deficiency symptoms after periods of from 7 to 21 weeks on experiment. These included muscular and nervous incoordination, partial loss of appetite, general weakness, night blindness, mild convulsions,

and general unthriftiness. Plasma vitamin A and C dropped lto low levels and semen quality was low in the deficient rams. Hemoglobin level of the blood was not affected. Neither testosterone propionate nor pregnant mare serum exerted any beneficial influence on semen quality of vitamin A deficient rams. A high percentage of the deficient rams had cystic pituitary glands at autopsy.

Several rams in both the deficient and vitamin A supplemented lots developed urinary calculi during the experiment.

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ABSTRACTS OF PAPERS TO BE PRESENTED AT THE FORTY-FIRST ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meetings are scheduled to be held at the Hotel Sherman in Chicago on November 25 and 26, 1949 with a dinner for the honor guest on November 28. Abstracts have been submitted for the following papers:

Breeding and Genetics Section

E. J. Warwick, *Chairman*

COMPARATIVE TESTICULAR DEVELOPMENT OF SOME INBRED, PUREBRED, CROSSBRED AND LINECROSS BOARS. F. N. Andrews and E. J. Warwick, *Purdue University.*

The testes of over 200 boars ranging in age from 70 to 140 days were studied grossly and microscopically. Comparisons were made between males of the following lines of breeding: Inbred White King, Inbred Landroc, White King×Landroc (linecross), Landroc×linecross (backcross), Duroc×Chester White (crossbred) and purebred Duroc. Sperm were present in the testes of the Durocs rather consistently at 110 days and in the backcross and crossbred pigs at 120 days. In the White King and Landroc boars sperm were present at 130 days. There appeared to be some variation in the linecross pigs. In some males sperm were present as early as 110 days and in others not until 140 days. Detailed analyses of the relationships of growth rate and gonad development have not yet been made but it was observed that the linecross had the most rapid growth rate and that the Durocs were among the slowest growers.

STUDIES ON THE INHERITANCE OF COLOR MARKINGS IN HAMPSHIRE SWINE. Thomas C. Cartwright and Robert R. Schrode, *A. & M. College of Texas.*

The color markings of 128 pigs farrowed by ten sows and sired by three boars were studied to gain further knowledge as to the mode of inheritance of Hampshire coat color. A ratio of average belt width to crown-rump length was used as the phenotype for the belting characteristic. Studies of successive ratios of this type for the same individual showed the ratio to be so highly repeatable that only one set of measurements taken at any age is necessary to estimate accurately the ratio of average belt width to crown-rump length at maturity. Estimates of the heritability of this ratio by sib correlations, parent-offspring correlations, and intrasire regression of offspring on dam were consistently high (0.6 to 0.7). The presence or absence of white on the snout and on the tip of the tail was studied on a qualitative basis. The results of matings in this study indicated that presence of white on the snout is inherited as a simple Mendelian dominant and that presence of white on the tip of the tail is inherited as a simple recessive. Tentative recommendations are given as to the planning of matings for best results with respect to color markings.

RELATION OF COW FAMILIES TO MILK PRODUCTION, REPRODUCTIVE EFFICIENCY AND LONGEVITY. C. M. Chance and R. E. Mather, *Virginia Agricultural Experiment Station.*

Dairy Herd Improvement Association production records on 1168 cows in six herds, covering periods of 13 to 21 years, were adjusted to a mature equivalent, 4 percent fat-corrected milk basis. Groups of cows with three or more consecutive generations with production records were designated "families," all cows descending in the direct female line from the foundation cow being included. Records of production, reproductive efficiency and longevity for 882 cows in 89 families were studied by the analysis of variance. When pro-

duction records were classified only according to families, differences were significant in two herds; when classified by sire and family, sire differences were significant and family differences were not significant in these two herds. In one other herd sire differences were highly significant. Reproductive efficiency differed significantly among families in only one herd, and longevity did not differ significantly among families in any of the six herds. These data support the contention that, under the systems of breeding common in most herds, families, as designated in this study, are not sufficiently differentiated to receive much consideration in selection.

CROSSBRED EWES FOR THE PRODUCTION OF HOTHOUSE LAMBS. L. D. Christian and W. L. Henning, *The Pennsylvania State College.*

This study was made to compare the grade Merino with the different crosses to determine the best source for foundation stock for the commercial production of hothouse lambs, to determine which breed of ram is the best to use on the above ewe, to find the best marketing season and to determine the market weight which is most desirable. The [Shropshire × <Dorset × (Corriedale-Merino)>] cross yielded the highest percentage of higher grade lambs than the other crosses. The [Hampshire × <Hampshire × (Dorset-Merino)>] produced the highest percentage of the lower grade carcasses. Hothouse lambs should be marketed early in the season, although there is a great demand during the Easter season. The most desirable weights are from 32 to 36 pounds. Dressed lambs heavier than 36 pounds are preferred to those less than 32 pounds. Lambs below 25 pounds should not be marketed. The trend shows that the three-breed crosses [Hampshire × (Dorset × Merino)] and the [Dorset × (Corriedale-Merino)] ewes when bred to Shropshire and Southdown rams produced a higher percentage of higher grade carcasses.

PROLIFICACY AS A FACTOR IN THE GENETIC IMPROVEMENT OF FARM ANIMALS. R. E. Comstock, *North Carolina State College.*

There has been a great deal of interest recently in stimulation of superovulation and transplantation of ova as means for obtaining more offspring from selected females. This report is concerned with the increase in rate of genetic improvement from selection that would be possible if these technics are perfected and used. The problem was approached entirely from the genetic point of view; questions concerned with the workability, economy, or mass acceptance of the technics were not considered. The possible increase in rate of improvement depends in part on natural reproductive rates in both male and female and partially on the effectiveness of selection practiced among sires. Several situations with respect to these two factors are considered.

ONE YEAR'S RESULTS ON IMPROVEMENT OF SHEEP THROUGH SELECTION OF PERFORMANCE-TESTED AND PROGENY-TESTED BREEDING ANIMALS. W. H. Dameron, J. C. Miller, J. M. Jones, S. P. Davis and R. E. Patterson, *Texas Agricultural Experiment Station.*

A cooperative project with twelve leading breeders of Rambouillet sheep from over the State was initiated at the Ranch Experiment Station at Sonora. A total of 96 prospective stud ram lambs were developed on a growing ration in dry lot from July 21, 1948 to May 26, 1949, a total of 308 days under uniform environmental influences. Objectives are to evaluate lambs for rate of gain, fleece production, and mutton conformation, and to determine heritability of important economic differences when measured under the same conditions. Lambs were sheared, weighed and scored for face covering, skin folds and body conformation at the start and at the end of the test. At the conclusion of the test the fleeces were scoured, and staple length and fiber diameter measured. At a field day attended by 400 sheepmen immediately after the close of the test, all rams were displayed by sire groups and complete records were available on each ram and on each sire group. There were significant differences within and

between sire groups on rate of gain, face covering, weight of clean wool, staple length of wool and body conformation scores. Statistical analyses of these data show relatively high heritability for each of these important economic characteristics, indicating that considerable progress can be made by selecting from performance tested and progeny tested rams. Interest is high among purebred sheep breeders within and without the State, and there are now 130 prospective stud rams on test representing Rambouillet, Corriedale, Delaine, Merino and Debouillet breeds.

INBRED AND LINECROSS BOARS VERSUS NON-INBRED AND NON-LINECROSS BOARS USED IN TWO-SIRE HERDS ON WISCONSIN FARMS. R. M. Durham, A. B. Chapman and R. H. Grummer, *University of Wisconsin.*

The progeny of 15 inbred and linecross boars were compared with those of 18 non-inbred and non-linecross boars used in two-sire herds on 18 Wisconsin farms. Records were kept on the numbers of pigs per litter at farrowing, weaning and five months of age and individual pig weights at weaning and five months of age. No significant differences were found between the sires compared on the same farms for number of pigs farrowed and at five months of age. Rather consistent, but non-significant, differences in favor of the inbred and linecross boars' progeny were found for weight at five months of age. The productivity of the daughters of eight of these inbred and linecross boars was compared with that of the daughers of outbred boars on the same farms. Both groups of gilts were bred to the same sires. The only significant differences found were in the larger numbers farrowed and weaned by gilts sired by the inbred Beltsville Landrace-Poland-China boars.

THE SEMEN PRODUCTION OF RAMS UNDER RANGE CONDITIONS. L. Otis Emik and Clair E. Terrill, *United States Department of Agriculture.*

These data summarize the results of routine pre-breeding semen tests on potential stud rams grown under range conditions at Dubois, Idaho during the ten years from 1938 through 1947. About 90 percent of the successful trials used ewes in diestrus and approximately one-fourth of the rams, including ram lambs, would not serve any ewes under barn conditions. Successful thirty minute trials were obtained from 200 Targhees, 301 Columbias and 824 Rambouillets. A total of 3,480 ejaculates were collected giving a volume of 2.73 liters (average 0.78 cc.) and 7,536 billions of sperm with an average motility of 78 percent. Unregistered Rambouillets (439 trials) excelled registered ones in number of ejaculates per trial, volume per trial, concentration, total sperm and motility. Inbreeding coefficients were about 6 percent higher for registered than for unregistered Rambouillet rams. The semen characters of Targhees and Columbias were intermediate to the two Rambouillet groups, with Targhees having higher concentration and motility but lesser volume and fewer sperm per trial than Columbias. Motility, which decreased from 82 percent for lambs to 66 percent for 6 year old rams, was the only character exhibiting any consistent influence due to age of the ram. Two year old rams gave the best records, with one's, three's, and lambs following in that order. The years of 1940 and 1941, especially, were far below average in nearly all respects, while 1944 was the best year. Improvements in management were partially responsible for improved semen production in the later years.

IMPORTANCE OF HIGH MILK PRODUCTION IN BEEF COWS FOUND OVER-ESTIMATED. Warren Gifford, *University of Arkansas.*

Records of milk production were obtained on 57 Hereford, 12 Aberdeen-Angus and 13 Shorthorn lactations with the growth records of calves, in an attempt to determine the effects of milk production of beef cows on growth of calves. Cows and calves were kept on pasture nine to ten months. During remainder of year, they received silage, prairie hay, and 1½ pounds cake daily. Two to four pounds grain supplement was fed when lactations occurred during winter months. Creep feeding was practiced only during winter months and calves were

weaned at 8 months. The gross correlation between daily milk production of Hereford dams and daily gain in weight of their calves was .60, .71, .52 and .35 for the 1st, 2nd, 3rd, and 4th months respectively. The correlations for the following four months were not significant. The average daily milk production was 8.6, 7.8, 7.2, 6.0, 6.2, 4.7, 4.7, and 4.2 for the first to eight months respectively. The average daily gain for the calves was approximately 1.5 lbs. during each month. The correlation between milk production and gain in height at withers was less than with gain in weight. The milk production of Shorthorn and Angus cows was slightly higher. Evidence indicates that the maximum milk production normally attained during the first six weeks of lactation is affected by the capacity of the young calves to consume the milk. If milk is not removed from the udder the production from high producing cows seems to level off to 12 to 15 pounds daily before the normal decline occurs.

ESTIMATION OF GENERAL, SPECIFIC, AND MATERNAL COMBINING ABILITIES IN CROSSES AMONG INBRED LINES OF SWINE. C. R. Henderson, *Iowa State College.*

Single crosses among 12 inbred lines of Poland China swine developed at the Iowa Station were tested in 6 seasons. A total of 214 litters representing 77 of the 132 possible reciprocal crosses were farrowed. The number of litters per cross varied from 1 to 12. Traits studied were litter number and weight at 0, 21, 56, and 154 days. Methods were developed for estimating from these data the general combining ability and the maternal ability of each of the lines and for estimating the relative importance of general, maternal, specific, and sex-linkage effects as causes of differences among specific crosses. It was found in this population of lines that general combining ability accounted for not more than 5%, specific effects (dominance plus epistasis) for 5–15%, and maternal and sex-linkage effects for none of the variation among crosses. The method for constructing selection indexes to select lines to use as male parents, to use as female parents, or to use in specific single crosses was described. The relative efficiencies of line-cross and top cross tests for estimating general combining ability were studied. The line cross test not only estimates general combining ability more efficiently, but it also furnishes information concerning maternal, specific, and sex-linkage effects. Procedures for estimating the optimum number of lines to test with limited testing facilities were described.

SOME OF THE SOURCES OF VARIATION IN BODY WEIGHT, RATE OF GAIN, TYPE, AND CONDITION OF LAMBS RAISED UNDER FARM CONDITIONS. H. A. Karam, A. B. Chapman and A. L. Pope, *University of Wisconsin.*

The effects of type of birth (singles and twins), sex, year, flock, and sire on body weight at 25 weeks of age, daily gain from birth to market weight, daily gain on feed, type and condition were studied in 437 lambs raised in farm flocks. These lambs were sired by 23 rams leased to 13 commercial lamb producers during the period 1944–47. Eight lambs sired by each ram were brought into the Wisconsin Experiment Station at an average age of 25 weeks, and fed out in sire-progeny groups for approximately 11 weeks. For body weight at 25 weeks and daily gain from birth to market weight, single lambs were 6.2 and 0.02 pounds, respectively, higher than twins, and wether lambs were 3.5 and 0.02 pounds higher than ewes. All these differences were highly significant statistically. For daily gain on feed, however, twin lambs averaged 0.01 pounds higher than singles; wether lambs averaged 0.01 pounds higher than ewes. These differences were not significant. Single lambs scored significantly higher in body type and condition than twins. Ewe lambs scored insignificantly higher in both characters than wethers. Since type of birth, sex, year and flock had highly significant effects on nearly all the characters studied, it is suggested that adjustments for them should be made before comparing lambs from different sires under such conditions. Differences between rams on the basis of their progeny's records when adjusted for these factors were highly significant. The two-sire flock method was effective in detecting ram differences on a relatively smaller number of lambs per sire.

THE EFFECT OF SUCCESSFUL EMBRYO TRANSPLANTATIONS ON THE PROGRESS EXPECTED FROM SELECTION. W. H. Kyle, *United States Department of Agriculture.*

The theoretical effects of transplanting embryos from donor to host females were investigated as a possible means of increasing the rate of livestock improvement. Estimates were made of the upper limits which might be approached by successful techniques. Embryo transplantation would probably be of little value in swine improvement and its value in other classes of livestock would depend primarily on the number of offspring obtained per donor female. Repeated recoveries of embryos at regular intervals from donor females in which superovulation has been produced appear to be necessary in order to increase materially the progress from selection. In the first generation of embryo transplantation, an estimated maximum of 2.5 to 3.5 times the present rate of progress would occur under the specific assumptions used. Reducing the generation interval could increase this to 4.8 times but would not compensate for the loss of production from the donor female. In later generations progress from intraherd selection would be reduced to 1.1 to 1.7 times the present rate if each generation is a family of full sisters. Family selection could replace progeny testing of dairy sires and its value would be enhanced by the reduction in the intra-family phenotypic correlation. Embryo transplantation would be useful in the formation of inbred lines of cattle and sheep. The tentative results obtained indicate that embryo transplantation, when perfected, may be of value to experiment stations and large organizations but may not be economically feasible for the average livestock producer unless certain limitations can be overcome.

THE INTERVAL BETWEEN THE TIME OF OVULATION AND IMPLANTATION OF THE BOVINE EMBRYO. A. A. Melton, R. O. Berry, and O. D. Butler, *Texas Agricultural Experiment Station.*

Fifteen grade cows were bred and the time of ovulation was determined by palpation at intervals of four hours. These cows were killed from 676 to 816 hours after ovulation. The degree of placental development and the histological changes of the caruncles were observed for the different aged embryos. Weights and measurements were made on the embryos and the embryonic membranes. Implantation is a gradual process, and the first caruncles to be penetrated by the chorionic villi are the 3 or 4 which are located around the embryo. Preimplantation changes in the caruncle occur as early as 28 days after ovulation, but the actual invaion of the maternal tissue in the most advanced caruncles occurs at 33 days. Besides the disappearance of the surface membrane from the caruncles, the first maternal preimplantation change to be observed is the formation of pitted areas in the mucosa of the caruncle. These irregular pitted areas are caused by a thickening of the cytotrophoblastic cells of the chorio-allantoic membrane. Each proliferated cell mass on this membrane fits into a shallow depression in the caruncle. A cluster of these proliferated areas forms the placental spots which can be seen on the chorio-allantoic membrane as early as 31 days after ovulation. It is from these spots that the villi later develop. Prior to 33 days there is no intimate union between the embryonic and maternal tissue and during this preimplantation period the embryo receives its nourishment entirely from the uterine secretions.

ESTIMATES OF THE HERITABILITY OF BIRTH WEIGHT AND WEANING WEIGHT OF LAMBS. R. H. Nelson and G. Venkatachalam, *Michigan State College.*

Heritability estimates of birth weight and weaning weight of lambs were calculated from the records accumulated on five breeds in the Michigan State College flock during the period 1945 through 1948. An analysis of the records showed that significant portions of the variation in these weights were due to differences in sex, type of birth (single or multiple), and age of dam. On the average, birth weights of females were 5 percent less than males, lambs from mature ewes were 10 per cent heavier than those from two-year-old ewes, and single lambs were 22 percent heavier than twins. The corresponding figures at weaning were

6 percent, 5 percent, and 17 percent, respectively. All weights were adjusted for these differences before calculating heritability. Estimates were obtained for each breed separately and then combined in a weighted average. The heritability figures obtained for birth weight in these data were .72 ± .10 from an intra-sire regression of offspring on dam based on 504 pairs and .15 ± .17 by the paternal half-sib correlation method. For weaning weight the figures were .29 ± .14 by the parent-offspring method based on 348 pairs and .42 ± .21 by the half-sib method. The weighted averages of the two methods were .61 ± .09 and .33 ± .12 for birth weight and weaning weight, respectively. All weighted averages were obtained by weighting each individual estimate by the reciprocal of its squared standard error.

A SUBJECTIVE METHOD OF EVALUATING BREEDING ANIMALS IN BEEF HERDS—A CLASSIFICATION SYSTEM. Maurice L. Ray and Warren Gifford, *University of Arkansas.*

A system of subjective evaluation of beef animals in addition to body measurements, growth efficiency, and other performance records may be of value in measuring the general merit of breeding animals. To determine the agreement between judges and normal changes in animals during a lifetime when evaluated by fixed standards for type and body conformation, a method of classifying animals on external appearance was established. Seven groups—Excellent, Very Good, Good Plus, Good, Good Minus, Fair and Poor—were used with the "Good" group representing the average of the breed. Since 1940, 239 different animals in the Arkansas Station herd have been rated semi-annually. Several animals have been classified 15 different times by two or more judges (eight different judges have made classifications). Ratings were made on general appearance, breed type, head and neck, fore quarters, body, hind quarters, disposition and over-all classification. Analysis of the 2886 classifications show high agreement between judges on the Final Classification given individual animals. (Correlations ranged from .68 to .97.) Correlations between judges on ratings given other parts were somewhat lower, lowest being on disposition (range .28 to .79). The high repeatability of ratings given individual animals indicate that (1) the same standard was used during all stages of development, (2) most animals remained in or near the same classification during lifetime (3) seasonal differences in condition or finish had little influence on classification ratings.

PERFORMANCE-TESTING AND PROGENY-TESTING OF BEEF BREEDING STOCK AS AN AID TO SELECTION. R. E. Patterson, J. H. Jones, J. J. Bayles, R. V. Turnbough, *Texas Agricultural Experiment Station The Texas; A & M College System.*

An experiment has been in progress since 1942 at the Balmorhea, Texas substation, in cooperation with ranchmen of the Highland Hereford area, to determine the value of using sire and progeny testing as an aid to effective selection. Six to ten young progeny per sire were fed the same growing rations under similar condition. Records were taken of initial and final weights, body type, and certain body measurements on 814 young bulls and 104 heifers during the seven years. The intra-year half-sib correlation of gain for bulls was +.260 while that for heifers was +.304. It is logical to expect that this high degree of relationship may be partially due to greater similarity of pretest environmental conditions within sire groups as compared with those between sire groups. The data do not lend themselves to a critical test of this possible source of variation but the small correlation between initial weight and gain ($r = .063$) would seem to show that it may not be too important. This experiment indicates, therefore, that the ability for rapid gain is highly heritable. Selection based upon performance of the individual should thus prove the most effective in improving rate of gain in beef cattle. The greatest rate of progress at least in the initial stage, would be expected from mating superior performing animals irrespective of any predetermined breeding lines. Practically no relationship exists between type score and gain ($r = -.041$). The correlation between initial grade and initial weight was −.243, while initial grade and final grade are fairly highly correlated ($r = +.724$).

CURL SIZE IN KARAKUL LAMB FUR IN RELATION TO SIRE DIFFERENCES, SELECTION, AND HERITABILITY. Victor L. Simmons and Ralph G. Schott, *United States Department of Agriculture.*

This study analyzes data on curl size in day-old Karakul lambs produced during a period of eight years. About 100 lambs were available for study each season. The production period represents approximately three generations of sire selection and less than a two generation turn-over of ewe stock. Size of curl was evaluated on the basis of a 10 point scale ranging from 1 to 10 in which "1" is the smallest, and "10" is the largest size of curl. The coat of each live lamb was compared with a standard set of fur samples representing the 10 gradations in curl size. The average curl size represented in the dams remained nearly constant at a value of 5.0 for the period. The individual sires showed medium (4.0 to 5.0) or small (2.0 to 3.0) size curl as lambs and selection of sires was toward those that gave a higher proportion of medium and small curls in their lambs. The average curl size of lambs was equivalent to that of the dams at the beginning of the period, but at the end the average size of the curl on the lambs had moved to a point midway between the sire and dam averages, or 3.8. An intra-sire dam-progeny regression gave a heritability constant of 63.8 percent for the size of curl character. These findings indicate that the average curl size produced in the breeding flock can be shifted by a few generations of selection. The smaller curl sizes are generally preferred in the Karakul lamb-skin fur trade.

THE RELATION OF THE POST-PARTUM BREEDING INTERVAL TO REPRODUCTIVE EFFICIENCY IN THE DAIRY COW. N. L. VanDemark and G. W. Salisbury *University of Illinois.*

Analyses of the service records of 593 cows of the University of Illinois dairy herd including 1674 pregnancies confirmed by subsequent calving showed that: 1) Fertility level increased with the length of the post-partum interval to first service up to 100 to 120 days; 2) Nearly 2.6 services per conception were required on the average for cows first bred within 40 days after calving, while those bred first at an interval of 100–120 days after calving required approximately 1.7 services per conception; 3) For a postpartum interval to first service of longer than 120 days the number of services per conception remained fairly constant up to approximately 200 days, beyond which the required services per conception again increased; 4) The simple correlation between post-partum interval to first service and reproductive efficiency was not statistically significant; however, the data fit closely a second degree polynomial curvilinear regression, resulting in this case in a highly significant multiple correlation coefficient.

SELECTION OF SHEEP AND GOATS FOR RESISTANCE TO STOMACH WORMS, *HAEMONCHUS CONTORTUS.* Bruce L. Warwick, R. O. Berry, R. D. Turk and C. O. Morgan, *Texas Agricultural Experiment Station.*

Initial selections were from sheep which had previously been treated with copper sulphate and nicotine sulphate. Additions were from survivors of the groups tested without treatment in intensive exposure pastures. Three registered Rambouillet rams survived the test. Registered Romney and Cheviots were tried without success. Unimproved sheep were also used and were very effective in raising the level of resistance and in lowering the production of wool. 1940 through 1948 lambs whose sires and dams were resistant were compared with controls. The differences in survival rates over the nine years are highly significant. The last two seasons yielded survival percentages of 64 and 85 respectively which are useful levels. Progeny of resistant rams bred to unselected ewes were no better than the controls. This points toward the existence of polygenes of very low individual importance, making it necessary to have intense selection on both sides of the pedigree. Only male goats were tested in the earlier years. Survivors were bred to untested females, and the survival rate was very high, 71% vs. 33% for controls. Untested daughters of resistant bucks when bred to resistant bucks gave progeny with 83% vs. 31% survival for controls. It appears that we have a much higher level of plus genes, with possibly true dominance for resistance, in goats than with

sheep. Some of the sheep and goats selected for resistance are approaching standard levels of production of wool and mohair.

GROWTH RATES OF SOME INBRED, PUREBRED, CROSSBRED, AND CROSSLINE PIGS. E. J. Warwick and James R. Wiley, *Purdue University.*

Growth rates of crossline pigs produced from reciprocal crosses of inbred Chester Whites of the White King line and inbred Landrocs (a strain produced from a crossbred foundation of Danish Landrace×Duroc) were compared over a three year period with those of pigs produced by conventional breeding methods and raised under the same environmental conditions. Twenty-two litters produced from White King gilts bred to Landroc boars averaged 7.2 pigs raised and the pigs averaged 204 pounds at 154 days of age. Fourteen litters of the reciprocal cross averaged 5.1 pigs raised to an average 154 day weight of 203 pounds. Comparable figures for the twenty-seven conventionally bred litters were 5.2 pigs and 178 pounds. The latter group included purebred Durocs, crossbred Duroc×Chester Whites and crossbred Poland China×Chester Whites. In two of the three seasons the crossline pigs were heavier at 56 days of age but had a slightly lower percentage increase in weight from 56 to 154 days than the purebreds and crossbreds. This makes it difficult to determine whether the differences at 154 days were due to inherent growing ability of the pigs themselves or to pre- and postnatal maternal influences. The pigs from nine litters of inbred Landrocs and nine litters of inbred Chester Whites raised under comparable conditions during one of the years averaged 160 and 158 pounds, respectively, at 154 days of age.

WOOL ANALYSIS ON THE BASIS OF BREEDS, WEIGHTS, AND GRADES. H. L. Woehling and W. L. Henning, *The Pennsylvania State College.*

The object of this research was to study fleece grade and weight records of the sheep flock at The Pennsylvania State College which covered a period of twelve years, 1936 to 1947 inclusive. The breeds in the study include: Cheviot, Hampshire, Shropshire, Southdown, Merino, [Hampshire×(D×M)], (Dorset×Merino), [Dorset×(C×M)], and (Corriedale ×Merino). The study showed that all of the breeds and crossbreds, except Cheviot and Merino, produced their heaviest fleeces the first year. It was also found that the Cheviots, Hampshires, Southdowns, Shropshires, [Hampshire×(D×M)], and (Dorset×Merino) produced their finest fleece the first shearing. The (Corriedale×Merino), which is a later maturing cross, produced their finest fleeces the second year, and the Merino fleeces all graded fine Delaine regardless of age. All of the breeds produced 50 percent or more combing fleeces the first shearing. In comparing the fleece weights of the Merino crossbred ewes (hot-house ewes) with the pedigreed Merinos, the pedigreed Merino fleeces averaged 3.33 pounds heavier than the crossbred fleeces. Averaging the weights of the combing and clothing fleeces of all breeds revealed the combing fleeces averaged 1.38 pounds heavier than the latter. A study covering all breeds of the comparative weights of quarter blood and three-eighths blood fleeces revealed the former averaged 1.51 pounds heavier than the latter. The results show that culling according to fleece weights and grades would be a very successful method.

Extension Section

Grady Sellards, *Chairman*

(No abstracts)

Investigations Symposium

G. E. Dickerson, *Chairman*

PROBLEMS, TECHNIQUES AND EXPERIMENTAL DESIGNS IN ANIMAL INVESTIGATIONS. BREEDING AND GENETICS. L. N. Hazel, *Iowa State College.*

The rate of genetic improvement expected from applying a definite breeding plan to a particular population is mathematically predictable provided certain biological, economic and

genetic constants are known. The scientific application of animal breeding consists of obtaining estimates of these constants and integrating them into the alternative plans possible for each class of livestock. From this one can compute the rates of improvement likely to result from various combinations of methods of selection and of mating systems. Then general plans having maximum effectiveness per unit of cost or per unit of time can be formulated and recommended for practical breeders. The important biological parameters such as (1) reproductive rates, and (2) generation intervals, can be estimated from the vital statistics of farm animals. The economic parameters, such as relative economic values of the several characters in which improvement may be desired, can be estimated from market summaries and cost accounting records of farm livestock enterprises. The genetic parameters, such as (1) heritability, and (2) genetic correlations between characters, can be estimated from the observed correlations between related individuals. Still others, such as (3) dominance and epistatic variance and (4) interactions between genotype and environment, can be estimated accurately by resorting to inbreeding and crossing inbred lines, from comparing identical and fraternal twins, or from other types of experiments designed expressly for the purpose in hand.

PROBLEMS, TECHNIQUES AND EXPERIMENTAL DESIGNS IN ANIMAL INVESTIGATIONS.—PHYSIOLOGY. L. E. Casida, *University of Wisconsin.*

Emphasis is placed on the problems of developmental physiology of economic characters and pathological states and of the determination of association or independence between physiological processes. Study of an economic character should include (1) Determination of stages in development at which the effects of environmental influences cause major variation in the final character; identification of the influences and evaluation of the quantitative relationships between the character and the influencing factor. (2) Determination of the heritable variation in the successive steps of its development; evaluation of the potential worth of such knowledge in selection, i.e., in regulation of management practices to increase heritable portion of the variations, in adjustment of records, and in formulation of selection indexes. A study of pathological states should include: (1) Identification of the origin of the predisposing variation and (2) Determination for each successive step in its development, its heritability and susceptability to environmental influences. Association or independence between different physiological characters may well be studied within and between different inbred lines subjected to different controlled environmental factors. Most creative research must be done in preliminary experiments, often "catch-as-catch-can." Each part of a plan must be tried out to such an extent that a guess can be made as to its course and outcome before an elaborately designed more critical experiment is justified.

Meats Section

K. F. Warner, *Chairman*

CERTAIN CHEMICAL CHARACTERISTICS OF CONNECTIVE TISSUE FROM DIFFERENT AGED ANIMALS. R. W. Bray, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

Elastin and collagen connective tissues were taken from U. S. Good and Utility veal carcasses; from U. S. Good beef carcasses and from U. S. Utility cow carcasses. Moisture, ash and fat determinations were made from the tissues and the data were treated statistically. In addition, hydrolysis experiments were made in an effort to determine differences between the connective tissue of different aged animals. Various normalities of acid hydrolysis accelerated by the autoclave were used on the elastin samples. In the case of collagenic connective tissue it was necessary to use acid hydrolysis at 37 degrees centrigrade and room temperature for 24 hours in order to find any difference in rate of hydrolysis. The difference in moisture content between samples of U. S. Good veal, beef, and Utility cow beef was highly significant at the 1 percent level. The ash content of the same tissues followed a similar trend to that of moisture with the veal samples being highest in both cases. The collagenic connective tissue was

definitely higher in ash and moisture than the elastin samples. On the basis of the data received, the fat content increases as the animal becomes older. When the elastin samples were treated with .1 N HCl and autoclaved for 1 hour, 15 percent more hydrolysis took place in the veal elastin samples than in the U. S. Good beef and 20 percent more than in the U. S. Utility cow elastin. Rate of hydrolysis for collagenic connective tissue was the same for all samples when treated with HCl and then autoclaved. However, when the samples were allowed to hydrolyze at 37 degrees centigrade for 24 hours, there was found a real difference in rate of hydrolysis between the U. S. Good beef samples and the U. S. Utility veal samples.

THE RELATIONSHIP BETWEEN SPECIFIC GRAVITY AND CERTAIN PHYSICAL CHARACTERISTICS OF THE PORK CARCASSES. C. J. Brown, J. C. Hillier and J. A. Whatley, *Oklahoma A. & M. College.*

Measurements, yields of wholesale cuts, and specific gravities were obtained on 66 pork carcasses from two different groups of hogs. Group I included 34 hogs from 3 inbred Duroc lines and their crosses. These hogs gained from 1.12 to 1.59 pounds per day and ranged in average backfat thickness from 1.38 to 1.93 inches. Group II included 32 individually fed outbred Duroc hogs. These hogs gained from 1.48 to 2.21 pounds per day and ranged from 1.41 to 2.62 inches in average backfat thickness. Chilled carcass weights ranged from 145 to 164 pounds. The average specific gravity on all carcasses as determined by hydrostatic weighing was 1.027 with a range from 1.012 to 1.037. Intragroup correlations of specific gravity with backfat thickness, area of loin eye, carcass length, percentage primal cuts, and percentage lean cuts were positive and highly significant. Highly significant negative correlations were found between specific gravity and backfat thickness, chilled weight, weight per inch of length and percentage of fat cuts. Correlations on Group II carcasses were slightly higher than on Group I carcasses. Specific gravity was more closely correlated with the above measurements than was backfat thickness or area of loin eye. The highest correlation was +.84 between specific gravity and percentage lean cuts. This indicates the possible use of specific gravity as a measure of carcass quality. Chemical analyses are being made of the carcasses in Group II. Correlations of fat percentage with specific gravity, backfat thickness and area of loin eye will be computed.

EFFECT OF FEEDING CITRUS OR CANE MOLASSES ON CARCASS QUALITY AND THE CONTENT OF CERTAIN VITAMINS IN PORK. R. B. French, A. M. Pearson, T. J. Cunha, V. Schmidt, O. D. Abbott, C. L. Anderson and R. S. Glasscock, *University of Florida.*

Using a basal ration of 71.5 percent ground yellow corn, 17.0 percent peanut meal, 10.0 percent alfalfa meal and 1.5 percent minerals for fattening pigs weighing approximately 150 pounds, 40 percent of the basal ration by weight was replaced with either citrus or cane molasses to obtain relative feeding values in comparison to corn. The feeding value of citrus and cane molasses appeared to be about equal, being approximately 78 percent as valuable as corn by weight. Palatability scores, dressing percentage, average daily gain, thickness of backfat and firmness of the carcass will be presented. The amount of thiamine, riboflavin and niacin in each ration and in certain tissues taken from the carcasses of all animals will be given.

TECHNICAL AND OPERATIONAL PROBLEMS OF SELF-SERVICE MEAT MERCHANDISING. Joseph S. Gowland and L. J. Bratzler, *Michigan State College.*

The object of this investigation was to study some of the problems found in prepackaged meat on a commercial basis. The first observations were to compare the weight loss, color preservation, and serviceability of Cellophane 300—MSAT—80 with .0015″, .0010″, and .0007″ aluminum foils. With a temperature of 34° and relative humidity of 85–90 percent, and using 24, 48, and 72 hour test periods, the following weight losses were obtained in 16 tests using approximately 400 packages: Cellophane, 2.09%; .0015″, 1.14%; .0010″, 1.42%;

.0007", 1.18%. The color was acceptable in most all of the packages. The serviceability was found to be good with the exception of the .0007" aluminum foil which lacked sufficient tensile strength. Boneless as well as bone-in beef cuts were used, but with small steaks the difference in drip loss was insignificant. A weight loss test was conducted in one of the cooperating markets and the following weight losses were observed: Cellophane, 2.59%; .0015", 1.75%; .0010", 1.67%; and .0007", 1.63%. Aluminum foil is a very efficient material when weight loss alone is considered. Stacking and handling increases the weight loss. In a survey to determine the packages that had to be rewrapped or remerchandised, it was found necessary to rewrap approximately 5% and to remerchandise 0.12% of all packages wrapped. In a consumer survey it was found that 62.5% of the customers purchase meat, the average purchase being 2.5 packages.

THE TENDERNESS OF BEEF IN RELATION TO DIFFERENT MUSCLES AND AGE OF THE ANIMAL. R. L. Hiner and O. G. Hankins, *United States Department of Agriculture.*

Samples were used from 52 beef animals slaughtered under uniform conditions and the carcasses chilled and aged at 34° F. for approximately 14 days. These carcasses were from 8 cows with an average age of 5½ years, 8 heifers 3 years, 25 steers 16 months, 8 weanling calves 8 months, and 3 veal calves 2½ months. In all cases the tenderloin muscle was the most tender, followed by the loin end, rib, shortloin, and two chuck samples which differed little and did not maintain consistent rankings in reference to each other, and then the round. The least tender samples were from the neck and foreshank. The 3 large muscles of the round—semimembranosus, semitendinosus and biceps femoris—ranked in that order in tenderness and all were less tender than the average for the entire round represented by 9 samples. With samples from the veal calves the most tender and samples from the cows least tender, the other 3 groups of animals were intermediate and decreased in order of tenderness with increase in age. Tenderness was not associated with grade of carcass to any appreciable extent among 8 Choice, 9 Good and 8 Commercial grade steers ranging from 14 to 18 months in age.

BACTERIAL STUDIES RELATED TO THE KEEPING QUALITY OF FROZEN PORK SAUSAGE. Robert L. Henrickson, *Kansas State College.*

The bacterial flora of fresh frozen pork and its effect upon the length of storage has received little consideration since freezer storage of food products became an accepted method of food preservation. The possible deleterious influence of bacteria upon the keeping quality is the characteristic with which this paper is concerned. Observations of the constituents used in fresh pork sausage indicated that rapid chilling, proper management, and clean condiments were very essential in retaining quality during freezer storage. Large numbers of organisms were found to be conducive to off-flavors and rancidity development. Palatability scores of the quality were found to correlate closely with the quantity of bacteria in the sausage.

VARIATIONS IN FATTENING PERFORMANCE OF TYPICAL BEEF, DAIRY AND DUAL-PURPOSE STEERS. Johnny Matsushima, P. A. Anderson, A. L. Harvey and W. J. Aunan, *University of Minnesota.*

Four pairs of Hereford steers differing in visual physical appearance and body type, two pairs of Red Poll steers and two pairs of Holstein steers representing beef, dual purpose and dairy breeds respectively were included in the study to determine the efficiency of feed utilization, rate of gain and comparative increase in bone, lean and fat in the carcasses. One animal of each pair was slaughtered in thin condition at the beginning of the test to obtain the initial carcass composition. The other animal was retained for fattening and then slaughtered after reaching approximately 950 pounds. The carcasses were graded and 9-10-11 rib samples were used for the determination of fat, bone and lean percentages. The rib cuts from Hereford

carcasses showed a very thick layer of fat covering over the eye muscle. On the other hand, a very uniform layer of fat of less thickness was found in the Red Poll carcasses. The fat covering in Holstein carcasses was not as thick as was found in the Herefords and the layer of fat was not uniform. Greatest change in carcass constituents was found in the increase of lean content in proportion to the ether extract content which was shown by the Red Polls. Also the Red Poll carcasses showed a greater decrease in percentage of bone content than either Hereford or Holstein carcasses with advancing weight and finish. The total fat content in Holstein carcasses showed the greatest increase while the Red Poll carcasses yielded a smaller quantity of body fat. However, the difference in increase of fat content was not very great among the three types of carcasses.

THE INFLUENCE OF RATE OF FREEZING AND LENGTH OF FREEZER-STORAGE UPON THE QUALITY OF BEEF OF KNOWN ORIGIN. A. M. Pearson and J. I. Miller, *Cornell University.*

Two experiments were conducted in which 282 steaks cut from 19 different steer carcasses were frozen at either a slow (approximately 20 hours), intermediate (about 5 hours), or rapid rate (about 1 hour), and held at 0° F. for varying periods of storage. An additional 28 steaks were analyzed in the fresh condition as controls. Steers full-fed corn, either on pasture or in dry lot, yielded higher dressing percentages, graded higher, both on foot and in the carcass, and yielded steaks which were lower in moisture and which were more tender than steaks from similar steers fattened on grass alone. The rates of freezing used in this study did not appear to alter cooking losses, total weight losses, expressible fluid, tenderness or palatability. However, the color of lean became progressively lighter as the rate of freezing was increased from slow to rapid. Freezer-storage caused a significant increase in cooking losses, total weight losses, drip and expressible fluid, which became apparent at the end of 90 days storage. Also, freezer-storage resulted in a decrease in tenderness. Thus, this study indicates that for the rates of freezing studied there was little or no effect on the over-all quality of beef while freezer-storage resulted in a marked loss of quality.

Nutrition Section

Burch H. Schneider, *Chairman*

A DEFICIENCY OF VITAMIN B_{12} IN A PRACTICAL RATION FOR WEANLING PIGS. G. C. Anderson and A. G. Hogan, *University of Missouri.*

Three ten-week trials with weanling pigs were conducted in order to determine the value of a vitamin B_{12} concentrate when added to rations made up of practical feedstuffs. In each trial the largest and most thrifty pigs received the basal corn-soybean ration while the smallest and least thrifty pigs were fed the basal ration supplemented with a vitamin B_{12} concentrate so as to add 10 mcg. of the vitamin per pound of feed. A third group, intermediate in size and thrift, was fed a ration which contained fish meal and is believed to be nutritionally complete. In Trial I the average daily gains were: Basal groups 0.69 lbs., vitamin B_{12} group 0.82 lbs., and fish meal group 0.92 lbs. During the last four weeks of the trial the average daily gains were: Basal group 0.86 lbs., vitamin B_{12} group 1.14 lbs. and fish meal group 1.36 lbs. Trials II and III are incomplete, but thus far results are parallel with those observed in Trial I.

THE INFLUENCE OF STILBESTROL AND TESTOSTERONE ON THE GROWTH AND FATTENING OF LAMBS. F. N. Andrews, W. M. Beeson and Claude Harper. *Purdue University.*

Ten lots of blackface wether lambs averaging 71 lb. were fed a fattening ration for 68 days. Five treatments were used in duplicate. (1) Control, (2) 12 mg. pellet of stilbestrol implanted subcutaneously, (3) 24 mg. pellet of stilbestrol implanted, (4) 10 mg. pellet of testosterone implanted subcutaneously, (5) 10 mg. pellet of testosterone implanted at start of ex-

periment and 10 mg. 43 days later. The average daily gains of the control lambs were 0.35 lb. Groups 2 and 3 gained 0.49 and 0.50 lb. daily and groups 4 and 5, 0.43 and 0.41 lb. per day. The gains in groups 2, 3, and 4 were significantly greater than the controls and the feed required per pound of gain in all treated lots were significantly less than the controls. Carcass quality appeared to be improved by the administration of testosterone.

THE METABOLISM OF COBALT IN LAMBS. D. E. Becker and Sedgwick E. Smith, *Cornell University.*

Two experiments, using lambs made cobalt-deficient by feeding a ration of shelled yellow corn, powdered whole milk, and cobalt-deficient grass hay, were conducted to determine the metabolic role of cobalt in ruminant nutrition. In test 1, the digestibility of the above ration was determined with six cobalt-deficient lambs and six positive control lambs which were being fed cobalt salts. Results indicated that the cobalt-fed lambs more efficiently digested the ether-soluble and the nitrogen-free extract fractions of the ration. However, the deficient-lambs showed a significantly greater coefficient of apparent digestibility for the fibrous fraction of the ration; an effect attributed to depressed feed intake. Apparently cobalt deficiency does not markedly affect the cellulose splitting microorganisms of the rumen. In test 2, fifteen deficient lambs were divided into six groups: I No treatment, II 10 mg. daily of pteroylglutamic acid injected, III 1 mcg. of vitamin B_{12} and 1 mg. of cobalt daily injected simultaneously, IV 15 U.S.P. units daily of Lilly liver extract injected, V 15 U.S.P. units daily of Lilly liver extract fed, and VI 1 mg. daily of cobalt fed. All injections were administered subcutaneously. Cobalt feeding gave the usual beneficial response; whereas, the negative controls continued to show a depressed appetite, body weight losses, and low hemoglobin level. Therapy with pteroylglutamic acid or vitamin B_{12} with cobalt were without effect. Subcutaneous injections of the liver extract were beneficial as measured by all criteria; however, oral dosage of the liver extract was of no therapeutic value. Preliminary attempts to concentrate the active principle from the liver extract by means of counter-current distribution were unsuccessful.

THE RELATIONSHIP OF MANGANESE TO CHOLINE SYNTHESIS AND UTILIZATION. Orville G. Bentley, R. R. Grunert and Paul H. Phillips, *University of Wisconsin.*

The relationship of manganese to the utilization of a choline-precursor, dimethylaminoethanol, by the growing chick has been studied. Day-old chicks were placed on the basal ration, deficient in manganese and choline, for 10 days. Then the basal ration supplemented with choline, manganese, dimethylaminoethanol, and methionine,either singly or in combinations, was fed during a four week growth trial. It was found that chicks receiving the manganese deficient ration supplemented with choline grew better than chicks fed the same ration supplemented with dimethylaminoethanol or dimethylaminoethanol plus methionine. However, when all these rations were supplemented with manganese, the growth equalled the positive control, i.e., the basal ration plus choline and manganese. Since the major deficiency of the basal ration was choline, it was reasoned that the growth of the dimethylaminoethanol fed chicks was limited by the rate of conversion of the choline precursor to choline by methylation. The addition of manganese to the rations containing dimethylaminoethanol permitted a greater growth rate than that obtained when manganese was added to the choline rations. These experiments indicate that manganese can function in the methylation reactions concerned with choline synthesis. This is not the only growth promoting function of manganese as growth was stimulated by manganese when it was added to rations adequately supplemented with choline. When both manganese and choline were added to the basal ration, the increase in growth was not additive but synergistic in character.

THE VITAMIN A AND VITAMIN C CONTENT OF SOW'S MILK, BLOOD AND LIVER, AND THE VITAMIN D CONTENT OF THE MILK. J. P. Bowland, Li-min Wu, R. H. Grummer, P. H. Phillips, and G. Bohstedt, *University of Wisconsin.*

A study was made of the influence of ration and season on the vitamins A and C content of the blood and milk of sows, and the liver vitamin A storage, and correlations between these

vitamin concentrations. Poor growth, conception, and reproduction in dry-lot sows and congenital malformations among their newborn pigs were not attributed to vitamin A deficiency. Blood levels of vitamin A were not influenced by diet. Milk vitamin A, and particularly colostrum vitamin A, was correlated with liver vitamin A storage, which in turn was related to the ration. Spring milk was much lower in vitamin A than winter milk. There was no definite difference due to ration or season in vitamin C content of the blood and milk. There was no difference between lots in vitamin D content of the milk. There was a tendency to show seasonal variation but appreciable winter storage of vitamin D was indicated.

THE USE OF AN ARTIFICIAL RUMEN IN STUDYING ROUGHAGE DIGESTION WITH RUMEN MICROORGANISMS UNDER CONTROLLED LABORATORY CONDITIONS. Wise Burroughs, Paul Gerlaugh and R. M. Bethke, *Ohio Agricultural Experiment Station.*

Roughage digestion in cattle and sheep is primarily dependent upon enzymes secreted by micro-organisms living within the rumens of these animals. Total digestion experiments with ruminants have been numerous in the past in attempts to determine influential factors governing the efficiency with which a roughage is utilized. A more direct method of studying fundamental factors in roughage digestion would be a study of the physiology of rumen micro-organisms which actually carry out the digestion. The work reported concerns a technic in which rumen conditions are simulated in the laboratory and in which rumen micro-organisms are observed with respect to their ability to digest cellulose and other roughage constituents. This method was developed using filter paper as the only source of roughage (cellulose) to which various known and unknown materials were added in studying their influence upon cellulose digestion. The method was extended to 4 good quality roughages and 4 poor quality roughages. The good quality roughages were digested efficiently without supplementation. The poor quality roughages required supplementation for maximum cellulose digestion. Two of the most potent supplements which greatly increased rumen micro-biological digestion of poor quality roughages were a complex mineral mixture and an autoclaved water extract of cow manure.

THE GROWTH OF YOUNG LAMBS ON SYNTHETIC RATIONS. R. Culik, R. W. Luecke, F. Thorp, Jr., R. H. Nelson and L. H. Blakeslee, *Michigan State College.*

A successful attempt was made to raise 3-day old lambs on a synthetic milk ration. The ration contained (on a dry matter basis) casein, 30%; glucose, 28%; lactose, 10%, lard, 26%; salt mixture, 6%. In addition the ration contained all of the fat and water soluble vitamins. This ration was made up to contain 16% solids. Eight lambs were fed this ration until a weight of 25 lbs. was reached. The average daily gain of these animals was 0.47 lbs. Another group of 7 lambs were fed the riboflavin deficient synthetic milk. At about the fourth to sixth day of the experiment the lambs ceased to gain in weight and for the next four to five days no gain or loss was noted. Shortly after this the animals lost weight. Usually the lambs did not live beyond the twentieth day of the experiment unless riboflavin treatment was started. Outside of a decreased growth rate and lowered appetite none of the symptoms of riboflavin deficiency which have been reported in the calf were found in the lamb. All of the seven lambs in the riboflavin deficient group developed pneumonia. This pneumonia was cured in the two deficient lambs which were given supplementary riboflavin. Since none of the lambs in the control group developed pneumonia it must be concluded that the riboflavin deficiency was, in some way, related to the onset of this disease.

EFFECT OF ANIMAL PROTEIN FACTOR SUPPLEMENT, B_{12}, METHIONINE, AND SOIL ON CORN RATIONS SUPPLEMENTED WITH PEANUT, SOYBEAN, AND FISH MEALS. T. J. Cunha, J. E. Burnside, H. H. Hopper, A. M. Pearson, and R. S. Glasscock, *University of Florida.*

Ninety-three pigs weighing 18–33 pounds were fed 5–6 weeks in four experiments. Control rations of corn, bone meal, limestone, salt, A, D, thiamine, riboflavin, niacin, pantothenic

acid, pyridoxine, choline, folic acid, and either peanut meal, soybean oil meal or fish meal were used. Lederle APF supplement caused pigs on corn-peanut meal rations to gain ¾ to 2½ times as fast as controls and pigs on corn-soybean rations to gain about 30 percent faster than their controls. APF supplement was thus more beneficial with peanut meal rations. The addition of APF supplement to corn-peanut meal and corn-soybean meal rations resulted in gains similar to those on corn-fish meal ration (protein content same in all rations). The Lederle APF supplement supplied an unknown factor(s) which increased the feeding value of peanut meal and soybean oil meal so that they were similar to the fish meal used. APF was even slightly beneficial with corn-fish meal ration. Vitamin B_{12} (charcoal and Fuller's earth) concentrates did not benefit pigs fed corn-peanut meal rations whereas five percent soil supplied unknown factor(s). B_{12} and APF supplement were different in their response on growth of the pig. Methionine increased growth when added to the corn-peanut meal ration. However, methionine was of no benefit when added to the same ration if it contained APF or B_{12}. This suggests some relationship between APF supplement and B_{12} to methionine and possibly protein needs of the pig.

THE EFFECT OF AGE, SEASON AND BREED UPON THE LEVEL OF CERTAIN BLOOD CONSTITUENTS OF BEEF CATTLE. A. E. Darlow, O. B. Ross, R. A. Long, R. W. MacVicar, and W. J. Van Arsdell, *Oklahoma A. & M. College.*

Ten cows and five heifer calves of each of the three beef breeds (Angus, Shorthorn and Hereford) were bled at monthly intervals over a two year period to study the levels of certain blood constituents. Plasma calcium, inorganic phosphorus, carotene, vitamin A and ascorbic acid determinations were made. The cattle were all managed alike. They were grazed on native grass range both summer and winter except for a brief period when they were brought to the barn to be rebred following calving. During the winter, a limited amount of prairie and alfalfa hay and atlas sorgo silage was fed in addition to the dry grass, and cottonseed cake was fed as the protein supplement. Consistent breed differences were not observed for any of the blood constituents studied. Considerable seasonal variation in plasma carotene was observed. Levels below 75 mcg. per 100 ml. of plasma were observed during the winter months in the mature cows and levels as high as 1200 mcg. per 100 ml. were observed during the summer grazing months. Less seasonal fluctuation in plasma vitamin A was observed. Ascorbic acid values were found to decrease during seasons of extremely high or low mean temperature. Low levels were found during August, September and February which were the months of extremes in temperature. Young growing heifers were found to have higher plasma inorganic phosphorus levels than did mature animals. Differences in the levels of the other blood constituents studied were less marked between the young and mature animals.

COMPARISON OF HIGH AND LOW PROTEIN CORN FOR SWINE. F. A. Dobbins, J. L. Krider, T. S. Hamilton and S. W. Terrill, *University of Illinois.*

In a pilot test 24 young, white, male rats were trio-fed (equal food) for 6 weeks to compare yellow corns containing 8.6%, 11.2% and 13.5% crude protein (fresh basis). In each diet the amount of protein supplied by corn was the same. The diets were equated for crude protein (15%) and energy. No statistically significant differences in growth rates were obtained. Nine pairs of 56-lb. pigs were pair-fed (equal feed) for 8 weeks to an average final weight of 132 pounds. One ration contained low protein corn (8.2%) while the other contained high protein corn (11.7%), and in each ration the amount of protein furnished by corn was the same, with the remainder being supplied by a supplement containing equal parts by weight of meat and bone scraps, dehydrated alfalfa meal and solvent soybean meal. The rations were equated for energy and contained 15% crude protein until the pigs reached 100 pounds and 12% thereafter. Average daily gains were the same (1.34 pounds) for both groups. Yellow corn containing 8.2% crude protein (fresh basis) was as efficient for young growing pigs as yellow corn containing 11.7% crude protein (fresh basis) when each furnished the same amount of protein in the ration.

BETAINE versus CHOLINE AND SOLVENT versus EXPELLER SOYBEAN MEAL FOR WEANLING PIGS. I. A. Dyer, J. L. Krider and W. E. Carroll, *University of Illinois.*

Six lots of 9 Duroc pigs each were self-fed a 20% crude protein corn-soybean meal ration in drylot. The treatments for lots 1–6 were as follows: (1) basal ration—63.5% ground yellow corn, 34% expeller soybean meal, 2% mineral mixture, 0.5% A and D oil and fortified with vitamins B_1, B_2, B_6, niacin, pantothenic acid and APF supplement; (2) the basal ration plus 250 mg. of choline per pound; (3) the basal ration plus 210 mg. of betaine per pound (choline and betaine are fed to supply an equal amount of methyl groups); (4) the same as (1) except that solvent soybean meal was fed instead of expeller meal; (5) the same as (4) plus 250 mg. of choline per pound; and (6) the same as (4) except that a "special" process (18 lb. pressure for 30 minutes) solvent soybean meal was used. The average daily gains indicated that neither choline nor betaine improved rations containing expeller or solvent soybean meal. Performance of pigs in lots 4, 5 and 6 indicate that both solvent and the "special" process solvent soybean meals were equal or slightly superior to the expeller meal for growth. Pigs in lot 1 (basal) exhibited rough hair coats and dry skins which were not observed in the other lots.

THE VALUE OF DRY IRON SALTS FED WITH SOLVENT EXTRACTED COTTONSEED MEAL IN PIG RATIONS. J. L. Fletcher and B. F. Barrentine, *Mississippi Experiment Station.*

In this experiment individually fed pigs were fed rations containing 25 percent solvent extracted cottonseed meal. The solvent meal fed contained two levels of free gossypol. These levels were .41 percent and .21 percent free gossypol. The low level of gossypol was secured by mixing equal parts of the .41 percent gossypol meal and a solvent meal containing only traces of free gossypol. Rations containing both levels of gossypol were supplemented with dry ferrous sulfate at four levels. These levels were 0.0, 0.25, 0.5 and 1.0 percent. The iron salt was mixed into the entire feed mixture in the dry form. This combination of 2 levels of gossypol and four levels of iron resulted in an eight pig test. Two replications were conducted. In both replications all pigs receiving no supplemental iron died. There was no statistical difference in the rate or economy of gain of the remaining pigs, regardless of level of gossypol or level of iron added. This experiment demonstrates the effectiveness of ferrous sulfate fed in a dry form and indicates that the amount of iron supplement required to provide protection is much less than has commonly been fed.

THE COMPARATIVE VALUE OF CORN SYRUP, LACTOSE AND GLUCOSE AS CARBOHYDRATE SOURCES IN SYNTHETIC MILKS FOR YOUNG CALVES. R. J. Flipse, C. F. Huffman, H. D. Webster and C. W. Duncan, *Michigan State College.*

Fifteen calves, nine Holsteins, four Jerseys, and two Brown Swiss, were allotted to the three experimental groups. Each calf remained with its dam for from four to 12 hours after birth, then was placed in an individual pen and started on the synthetic milk diet 24 hours later. Calves in all groups received rations identical except for the carbohydrate fraction. Group I (control) received glucose as the chief carbohydrate source. In group II corn syrup replaced the glucose in equivalent amounts ranging from 10 to 45 percent of the total dry matter. In group III lactose replaced glucose in equivalent amounts of from five to 30 percent. Performance of calves on lactose was superior to that on glucose or corn syrup. Lactose calves gained steadily from the start, at 28 day averaging 126 percent of their starting weight. Hair coats were healthy and feces of normal consistency throughout the trial. Glucose and corn syrup calves at 28 days averaged respectively 109 and 106 percent of their starting weights. All of this gain was registered during the latter half of the trial. Feces of calves on corn syrup became very soft the fourth day and remained soft throughout the trial. One lactose calf died of bloat while on experiment. Pneumonia occurred with about equal frequency in each group. Autopsies performed on representative calves disclosed a high incidence of white spotted kidney with no difference between groups, and some congestion of the small and/or large intestine in groups I and II.

EFFECT OF RATION UPON RUMEN FLORA OF CATTLE AND SHEEP. L. S. Gall, *National Dairy Research Laboratories, Inc.*

A study was made of the kinds and numbers of rumen bacteria found in cattle and sheep on various practical and experimental rations. The animals tested included cattle and sheep on fattening and breeding rations and pasture; cattle on dairy rations and simplified diet; and sheep fed cobalt-deficient rations and purified diets containing urea as the sole source of nitrogen. The samples were mostly taken by stomach tube, but a few were obtained from fistulated animals. Bacteriological examinations of the rumen contents were made by direct bacterial counts, Gram stains, and anaerobic cultural series. The results of the studies showed marked similarities among animals of both species fed the same type of farm ration, even though the tests were conducted at various times, in various parts of the country. There were quantitative differences in the number of fast-growing organisms as the grain in the ration varied, but few qualitative variations appeared. Animals on pasture had a higher bacterial count and showed a few new organisms in the Gram stain in addition to the regular morphological types. Sheep fed purified diets gave a different bacterial picture than those on farm rations. Fewer types of organisms were seen on the Gram stain and culturability was better. Cattle on simplified rations gave a bacterial picture intermediate between the farm and purified diets, varying sharply with the composition of the ration. Cobalt-deficient sheep showed a simpler flora and lower bacterial count than animals on the same ration plus cobalt.

CALCIUM AND PHOSPHORUS BALANCE STUDIES WITH LAMBS ON UREA RATIONS. Willis D. Gallup and H. M. Briggs, *Oklahoma A. & M. College.*

The possibility that urea added as a source of nitrogen to ruminant rations might have an unfavorable effect on calcium and phosphorus retention was investigated in a series of balance trials with lambs weighing from 50 to 70 pounds. The basal rations made up of natural feeds and a vitamin D supplement supplied from about 1 to 5 grams of Ca and 0.9 to 2 grams of P, daily. Urea was added to experimental rations of the same composition in amounts to supply from 1 to 6 grams of additional nitrogen. Positive nitrogen balances were obtained in all trials. Negative phosphorus balances were obtained with the rations which supplied daily less than 1.3 gm. of P. Calcium balances were usually negative in the absence of adequate phosphorus. Urea was without effect on calcium and phosphorus retention.

THE COMPARATIVE VALUE OF HYDRAULIC, EXPELLER AND SOLVENT OIL MEALS IN MAINTENANCE AND FATTENING RATIONS FOR RUMINANTS. Willis D. Gallup, H. M. Briggs, and E. E. Hatfield, *Oklahoma Agricultural Experiment Station.*

The comparative value of cottonseed meal prepared by hydraulic and solvent processes and soybean oil meal prepared by expeller and solvent processes was determined in digestion and nitrogen balance trials with steers and lambs. The meals were fed on an equivalent protein basis in amounts which furnished about 60 percent of the total nitrogen in maintenance rations of prairie hay and oil meal and about 28 percent of the total nitrogen in fattening rations of corn, prairie hay and oil meal. All rations contained about 10 percent of protein. Differences among the meals attributed to differences in processing were not evident in the results. The digestibility of nutrients was higher in the soybean oil meal rations than in the cottonseed meal rations of similar type for both steers and lambs. The cottonseed meal rations and the corresponding soybean oil meal rations were of equal value, however, in promoting nitrogen retention. The protein of the low carbohydrate maintenance rations was poorly utilized. The average percentage of total nitrogen intake retained by steers on the maintenance and fattening rations was 17.4 percent and 31.5 percent, respectively, and by lambs on these rations was 14.4 percent and 19.2 percent, respectively.

RAISING NEWBORN LAMBS ON "SYNTHETIC" MILK. U. S. Garrigus and B. Connor Johnson, *University of Illinois.*

Two newborn lambs, which had received colostrum from their dams, were raised for a period of approximately one hundred days on a "synthetic" milk diet which had previously

proven satisfactory for dairy calves and baby pigs. The growth rate was less than for lambs raised on their dams, probably due to at least two factors: (a) their desire for more company and attention than they received and (b) their need for higher food intake which might be obtained by more frequent feedings. One of the two lambs was raised on a riboflavin deficient diet. At four weeks of age his weight plateaued for three weeks but then increased and he grew at the same rate as the lamb raised on the "complete" diet. With considerable attention to the apparent psychological needs of lambs created when lambs are removed from their dams, this method of experimentation seems to offer good prospects for detailed study of prerumination nutrition in newborn lambs.

FISH SOLUBLES AND LIQUID FISH FOR GROWING AND FATTENING SWINE. H. B. Geurin, J. A. Hoefer and W. M. Beeson. *Purdue Agricultural Experiment Station.*

This study consisting of two dry lot feeding trials with swine (10 pigs per lot), presents the results of adding fish solubles or liquid fish to a swine ration of plant origin. The basal ration contained ground corn, expeller soybean oil meal, 5% sun-cured alfalfa meal, 0.125% fortified vitamin A and D oil, and a simple mineral mixture. The crude protein level of the rations was lowered as the pigs grew. In the first trial fish solubles was mixed into the basal ration at levels of 1 and 2% (wet basis) for lot 2 and lot 3 pigs respectively. The average daily gain for lot 1 pigs of only 1.03 pounds indicates an inadequacy in the basal ration. Both levels of fish solubles produced a significant increase in growth rate when compared to the basal ration as evidenced by average daily gains of 1.22 and 1.30 pounds for lot 2 and lot 3 pigs respectively. Feed efficiency results show approximately an 18% improvement in economy of gain for either level of fish solubles when compared to the basal ration. In the second trial, which duplicated the experimental design of the preceding trial, a fourth lot of pigs receiving 2% liquid fish was added. Since the pigs in lot 1 gained only 1.11 pounds per day, the basal ration was again inadequate. The average daily gains for lots 2, 3 and 4 were 1.41, 1.59 and 1.45 pounds respectively. Two percent level of liquid fish was equal to one percent fish solubles.

THE SODIUM AND POTASSIUM REQUIREMENTS OF THE RAT. R. R. Grunert, James H. Meyer and Paul H. Phillips, *University of Wisconsin.*

The interrelated growth requirements of the rat for sodium and potassium have been studied. The amount of sodium required was found to be 0.05 percent when 0.25 percent potassium was present in the ration. It was observed that an increased requirement for sodium resulted when the potassium was raised to 0.5 percent. This effect was evident only during the latter half of the experimental period of six weeks. The potassium requirement was not constant and decreased over a six-weeks period from 0.18 percent to 0.09 percent in the presence of 0.1 percent sodium. The effect of a high level of sodium (1.0 percent) which was evident only initially, was to lower the requirement of potassium. It would appear that high levels of sodium do have a slight sparing action on the requirement for potassium but that high levels of potassium are antagonistic and tend to increase the requirement for sodium. The data indicate that sodium can replace potassium to a slight extent, at least initially, and that potassium cannot replace sodium but rather is antagonistic to this ion when the latter is limiting.

VITAMIN B_{12} FOR GROWING PIGS. Fred Hale and Carl M. Lyman, *Texas A & M College.*

A vitamin B_{12} concentrate prepared by Merck and Co. was fed to young growing pigs in two tests. The check ration was composed of 70 pounds of yellow corn, 25 pounds of soybean oil meal, 3 pounds of alfalfa leaf meal, 1.5 pounds of pulverized limestone, and 0.5 pound of salt. This ration plus 1.5 milligrams of vitamin B_{12} per 100 pounds of feed was fed the pigs in the experimental group. The pigs in each group were fed in individual pens. In the first

test the pigs getting the B_{12} vitamin made 31 percent greater gains than did the pigs in the control group. Also, the pigs on the B_{12} ration required 22.7 pounds less feed per 100 pounds of gain than did the pigs on check ration. Results of the second test now in progress will be included in the final report.

THE EFFECT OF COBALT ON VITAMIN B_{12} SYNTHESIS IN THE RUMEN OF SHEEP. W. H. Hale, A. L. Pope, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

Since vitamin B_{12} has been shown to contain cobalt, the possibility exists that a cobalt deficiency in sheep may be due to a lack of vitamin B_{12} synthesis in the rumen. Rumen contents from cobalt deficient sheep and from cobalt supplemented sheep were assayed for vitamin B_{12} activity. Chickens were used as the assay animals. Five separate trials have shown that some growth factor(s) is missing from the rumen contents of the cobalt deficient sheep. The rumen contents of the cobalt supplemented sheep consistently gave from 30 to 40 gms. more chick growth during the assay period of 4 weeks than did the rumen contents from the cobalt deficient sheep. In some instances the cobalt deficient rumen contents gave less growth than the basal ration. This slower growth rate could be completely overcome by adding vitamin B_{12} to the ration of rumen contents from the cobalt deficient sheep. Addition of cobalt sulphate without rumen contents was ineffective in correcting the retarded growth. Feces from cobalt deficient sheep and cobalt supplemented sheep gave the same results as did the rumen content assays. Crystalline vitamin B_{12} injections were ineffective in alleviating the symptoms of cobalt deficiency. Oral administration of a crude concentrate of vitamin B_{12} to correct a cobalt deficiency resulted in a partial cure, but this may be due to the presence of some contaminant in the concentrate.

THE EFFECT OF IODINE, FISH SOLUBLES AND VITAMINS A AND B_{12} SUPPLEMENTATION ON THE REPRODUCTION AND LACTATION PERFORMANCE OF SOWS FED PLANT RATIONS. A. A. Heidebrecht, O. B. Ross, R. W. MacVicar and C. K. Whitehair, *Oklahoma A. & M. College.*

The study consisted of two experiments involving fifty-five gilts and sows. All of the experimental animals were confined to concrete dry lots from weaning age until the conclusion of the experiment. Thirty to sixty days prior to breeding, all gilts and sows were fed a basal ration composed of ground yellow corn, expeller soybean oil meal, 5% alfalfa meal, salt, and a calcium supplement. Iodine and crude carotene concentrate were added to the basal ration in experiment I, but omitted from the basal ration in experiment II. The following rations were fed: *Experiment I* (summer and fall 1948). *Gilts*—Lot 1, basal; Lot 2, basal+4% fish solubles; Lot 3, basal+10% alfalfa meal; Lot 4 basal+injectable liver extract; Lot 5, basal (confined to dirt lot); Lot 6 basal+Merck's APF Supplement. *Yearling sows*—Lot 7, basal; Lot 8, basal+4% fish solubles. *Experiment II* (Winter and spring 1949). *Gilts*—Lot 1, basal; Lot 2, basal+iodine; Lot 3, basal+iodine+vitamin A. *2 yr. old sows*—Lot 4, basal+iodine +vitamin A; Lot 5, basal+iodine+crude carotene concentrate; Lot 6, basal+iodine+vitamin A+4% fish solubles; Lot 7, basal+iodine+vitamin A+Merck's APF supplement. The average number of pigs weaned per sow and the average weaning weight per pig, respectively, were: *Experiment I*—Lot 1, 7.3, 19.8; Lot 2, 7.8, 22.8; Lot 3, 8.0, 20.9; Lot 4, 7.5, 20.2; Lot 5, 8.0, 21.2; Lot 6, 7.0, 22.1; Lot 7, 7.3, 21.5; Lot 8, 7.0, 26.0. *Experiment II*—Lot 1, 7.4, 22.2; Lot 2, 7.0, 21.2; Lot 3, 7.0, 21.6; Lot 4, 7.8, 23.4; Lot 5, 7.0, 26.9; Lot 6, 7.7, 24.9; Lot 7, 7.0, 23.1. Although the weaning weights differed somewhat no statistically significant difference was found among lots.

VALUE OF SUGAR BEET TOPS DEHYDRATED, ENSILED AND COCKED, AND DEHYDRATED GRASS FED TO FATTENING STEERS. W. W. Heinemann, H. P. Singleton, and M. E. Ensminger, *State College of Washington.*

Two consecutive winter experiments involving the use of 154 long-yearling steers were conducted in fattening trials on sugar beet tops (1) stack-ensiled, (2) trench-ensiled, (3) field-

cocked, and (4) dehydrated, and on dehydrated grass as (a) a grain substitute, and (b) an alfalfa replacement. The control grain ration was composed of two-thirds cracked barley and one-third dried molasses-beet pulp. This was fed with corn silage and alfalfa hay, two to one by weight. One-half the barley was replaced with (1) dehydrated beet tops and (2) dehydrated grass. Trench- and stack-ensiled and field-cocked beet tops replaced the corn silage in three respective lots and dehydrated grass replaced alfalfa in another, with the control grain ration being fed in these lots. Pea meal was used to balance the protein intake. Highest daily gains for the 90-day feeding periods were made by the steers fed the control ration, 2.00 pounds. Other gains were 1.79 pounds on dehydrated beet tops, 1.75 pounds on trench-ensiled beet tops, 1.75 pounds on field-cocked beet tops, 1.66 pounds on dehydrated grass fed as an alfalfa replacement, 1.46 pounds on dehydrated grass as a replacement for one-half the barley, and 1.37 pounds on stack-ensiled beet tops. Dehydrated beet tops in the ration did not delay attainment of a suitable market finish. However, beet tops fed as roughages and dehydrated grass fed as either a roughage or grain replacement appeared to lengthen the time required to attain a suitable grain-fed finish.

CAROTENE REQUIREMENTS OF GROWING PIGS. J. F. Hentges, Jr., R. H. Grummer, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

The carotene requirements of growing pigs have been studied. Four lots of 8 pigs each were used to compare two levels of dehydrated alfalfa with sun-cured alfalfa and pelleted dehydrated alfalfa. Results indicate that 3% dehydrated alfalfa and 3% pelleted alfalfa are adequate for growth and for maintenance of blood and liver vitamin A levels. Six percent dehydrated alfalfa in the ration doubled the liver stores. Three percent sun-cured alfalfa was equally adequate for growth but resulted in a drop in blood and liver vitamin A levels. Carotene analyses of alfalfa samples were made periodically to compare the stability of carotene during storage. In another trial, 20 pigs, 2 weeks of age, were raised in wire cages on a low-carotene diet until definite vitamin A deficiency symptoms were exhibited. At this time, pigs were allotted for supplementation with purified carotene at graded levels. Blood plasma vitamin A analyses, liver vitamin A determinations, spinal fluid pressures, night blindness tests, and rates of gain were recorded. Results indicate that spinal fluid pressures and plasma levels of vitamin A may be used to detect the onset of a vitamin A deficiency before severe symptoms (night blindness, etc.) are exhibited. Blood levels were correlated with liver stores of vitamin A. Data are presented showing the effects of supplementation with graded levels of purified carotene.

VITAMIN B_{12} AND PTEROYLGLUTAMIC ACID DEFICIENCY IN THE BABY PIG, WITHOUT THE USE OF ANTAGONIST. B. Connor Johnson and R. O. Nesheim, *University of Illinois.*

In previous papers we have described a "synthetic milk" diet for baby pigs which is deficient in vitamin B_{12}. We have also reported the production of a combined PGA-vitamin B_{12} deficiency in baby pigs by the use of this diet plus the PGA antagonist, "x-methyl" folic acid. We have now succeeded in producing in baby pigs a combined PGA-vitamin B_{12} deficiency without the use of an anti-vitamin. Baby pigs in which the combined deficiency had been produced by 8 weeks feeding on a vitamin B_{12}-PGA deficient "synthetic milk" diet (containing 20% soybean protein) gave a marked growth response and marked reticulocytosis upon vitamin B_{12} injection. After 3 weeks on vitamin B_{12} therapy a second reticulocyte peak was obtained following oral PGA supplementation. Baby pigs which had not received the vitamin B_{12} therapy also showed some reticulocytosis following PGA. However, the response was much less marked than in the pigs which were receiving vitamin B_{12}. It appears evident that, while there are some symptoms common to both deficiencies and some over-lapping in therapeutic action of the two vitamins, the pig requires both PGA and vitamin B_{12} for normal growth and maintenance of health.

THE EFFECT OF LEVEL AND SOURCE OF PROTEIN IN PREGNANT EWE RATIONS ON EWE PRODUCTIVITY. R. M. Jordan, Earle W. Klosterman, and James W. Wilson, *South Dakota Experiment Station.*

Five lots of 17 No-Tail ewes fed for periods of 102 days during 3 winters indicated that source and level (.15–.31 pounds per ewe) of protein in pregnant ewe rations did not materially affect ewe productivity. Ewes were bred before being placed on trial. Protein was supplied by alfalfa hay, brome hay and soybean meal. Other than varying amounts of protein fed, all other nutrients were fed at equal levels. Lot one received 3.5 pounds of alfalfa, lot two—1 pound of alfalfa and 2.5 pounds of brome, lot three—3.5 pounds of brome, lot four—3.2 pounds of brome plus 0.20 pounds of soybean meal and lot five—2.4 pounds of brome plus 0.68 pound of soybean meal. Total protein content in lots 1 and 5 were equal as was protein level in lots 2 and 4. The last 28 days .42 pound of shelled corn was fed per ewe in each lot. Productiveness of the ration was measured by gain of ewes, condition and vitality of lambs at birth, fleece-weight and daily gain of lambs produced. The various rations caused no significant differences in fleece weights, vitality of the lamb at birth or daily gain of the lamb. Highly significant differences between rations were noted for gain of ewe and significant differences in the condition of the lambs at birth. The mixture of alfalfa-brome hay ration cost about 15% less than the straight alfalfa ration. One pound alfalfa was equivalent to ¼ pound soybean meal in this experiment.

DIGESTIBILITY STUDIES ON DAIRY CATTLE: A COMPARISON OF THE TOTAL COLLECTION METHODS; CONVENTIONAL VERSUS CHROMIUM OXIDE AND LIGNIN TECHNIQUES. E. A. Kane, W. C. Jacobson, and L. A. Moore, *United States Department of Agriculture.*

Home grown alfalfa was cured in three different ways; (1) field cured, (2) barn cured and (3) ensiled. Digestion trials were carried out on the resulting hays and alfalfa silage to evaluate the effect of method of curing on the nutritional quality of the roughage. The three cows used in this experiment received the same ration of grain, corn silage, and alfalfa, with the TDN of the rations adjusted to the individual cow's milk production. Prior to the experiment chromium oxide was mixed with the grain. The digestibility coefficients of the ration were determined simultaneously by the total collection method and by chromium oxide and lignin analyses of the feeds and feces. If the percentage of any nutrient in the feeds and feces is known, and the percentage of either lignin or chromium oxide is determined in the feed and feces, the digestibility of that nutrient can be found by means of the following formula:

$$\text{Digestibility} = 100 - \frac{\%\ \text{Lignin in Feed}}{\%\ \text{Lignin in Feces}} \times \frac{\%\ \text{Nutrient in Feces}}{\%\ \text{Nutrient in Feed}}.$$

Six digestion trials of approximately nine days duration have been conducted on each type of forage. The digestibility of field-cured alfalfa was lower than the barn-cured or ensiled alfalfa. Our results indicate that the use of indigestible residues (such as chromium oxide or lignin) offer promise of saving time, labor and expense in conducting digestion trials.

SYMPTOMS OF INDUCED COPPER TOXICITY IN A STEER. R. W. Kidder, *Everglades Experiment Station.*

In studying the copper requirements of cattle and determining the maximum tolerance as well as the minimum requirement some cattle have been sacrificed by overdoses of copper sulfate as well as by withholding copper from the ration. One 500 pound steer developed chronic copper poisoning and died after 122 days on a daily drench containing 5 grams of copper sulfate ($CuSo_4 \cdot 5H_2O$). The symptoms, as illustrated by kodaslides, follow very closely those described for sheep by Broughton and Hardy in Texas Bulletin 499. This steer was a grade Angus yearling on St. Augustine grass pasture without supplementary feeds. The trial began in October 1948 and continued for 102 days when the steer developed inappetence and diarrhea. Following a partial recovery period of 26 days, the drenches were continued for 20 days

before prostration and death about 10 hours later. Postmortem examination revealed the typical generalized icterus; dirty-yellow colored fat and membranes; hemolysis; hemoglobinuria; urinary bladder distended with more than 2 quarts of brown to black urine; kidneys enlarged showing glossy black marbled surface when removed from the capsule; lungs poorly collapsed; spleen enlarged, soft and dark colored; liver a yellowish color with hard surface; and gall bladder distended with a dark colored material about the consistency of 600 W grease.

CITRUS PRODUCTS FOR FATTENING CATTLE W. G. Kirk, H. J. Fulford and George K. Davis, *Florida Agricultural Experiment Station.*

Citrus by-products are being produced in ever increasing amounts in Florida. Analyses show that all citrus products have a high energy value but, except for citrus seed meal, are low in protein. In a series of trials using citrus feeds, fresh grapefruit, fresh pulp, dried pulp and molasses, all animals were fed in addition hay, cottonseed meal and a complete mineral mixture. Experimental animals were grade two and three-year old Brahman steers fed individually in dry-lot. Four trials are reported. In a preliminary 120-day period steers fed equal amounts of dried pulp and molasses made an average daily gain of 2.55 pounds, while those fed three parts pulp and one part molasses gained 2.19 pounds. The total digestible nutrient requirement for 100 pounds of gain was 485 and 451 pounds respectively. In two trials steers fed equal parts of dried pulp and molasses made an average daily gain of 2.55 pounds, requiring 471 pounds of total digestible nutrients per 100 pounds gain, while animals given equal parts of dried pulp and cane molasses gained 2.27 pounds and required 514 pounds of nutrients. In a fourth trial two lots were fed the same quantity of dried pulp and given either citrus or cane molasses free-choice. The lot fed citrus molasses gained 2.60 pounds daily, that fed cane molasses 2.69 pounds with total digestible nutrient requirements per 100 pounds gain of 470 and 454 pounds respectively. The meat from the citrus-fed steers was of excellent quality.

CAROTENE AND VITAMIN A STUDIES WITH SHEEP. Earle W. Klosterman, D. W. Bolin and Merle R. Light, *North Dakota Agricultural Experiment Station.*

A group of lambs weighing an average of seventy-five pounds was placed on a ration of oat straw, dried beet pulp, barley, oats, soybean oil meal, bonemeal and salt. Good gains were made on this ration and the lambs became well finished. They became depleted of vitamin A in four to six months. The main deficiency symptoms noted were a muscular incoordination and excitability. Lambs that were on this ration for as long as eight months remained fat and developed no eye lesions. Crystalline carotene suspended in water with Tween 20 or carotene in cottonseed oil injected into the blood stream was very rapidly removed. This carotene apparently was not converted to vitamin A, however, as no increase of the vitamin in the blood or storage in the liver could be detected. Lambs given carotene by mouth or allowed green grass for a short period showed an increase of vitamin A in the blood serum. When no carotene was present in the intestinal contents no vitamin A was found in the intestinal wall even though there were large stores in the liver. When carotene was present in the intestine vitamin A was found in the intestinal wall. These observations coupled with the fact that no measurable amount of carotene is found in the blood of normal sheep suggest that carotene is converted into vitamin A during digestion and/or absorption rather than by the liver.

THE EFFECT OF THYROPROTEIN ON WOOL PRODUCTION. Pedro Labarthe, Eugene Bertone, and L. E. Washburn, *Colorado A & M College.*

Rambouillet ewes fed a ration of alfalfa hay, ground oats, and cottonseed meal were given supplements of thyroprotein ("Protamone") at levels of 0.5 gm., 1.0 gm., and 1.5 gms. per animal daily. Wool secretion was studied by means of observations on the total annual fleece yield, and on fiber length, diameter, grease, and suint salt determinations on samples shaved from a shoulder area of each animal every 28 days. While all of the sheep produced more wool under controlled experimental conditions than during the previous year on a commercial ranch, the two lots which received the higher levels of thyroprotein showed gains in

wool yield of 15 and 104 percent over that of the control lot. The increase of wool in the lot which consumed the low level of thyroprotein was approximately 16 percent less than that of the control lot. No appreciable differences were observed between supplemented and control lots with respect to length, diameter, or grease percentage of shaven samples. Suint salt content, however, was increased in the lot fed the highest level of thyroprotein. Changes in length, diameter, grease and suint salt of shaven wool were uniform and cyclic, and followed a definite seasonal pattern.

COMPARISON OF DIFFERENT SOURCES OF ANIMAL PROTEIN FACTOR FOR GROWING-FATTENING PIGS: K. C. Lepley, D. V. Catron and C. C. Culbertson, *Iowa Agricultural Experiment Station.*

Nine experiments involving 332 growing-fattening pigs were conducted during a two year study on vitamin B_{12} and other animal protein factor concentrates produced by microbial fermentation. Previous work indicated that 2% condensed fish solubles was equivalent to 4% fish meal, 5 or 6% meat and bonescraps, or 6% dried corn distillers solubles in supplementing an all-plant protein ration for optimum performance of growing-fattening pigs fed in concrete dry-lot. The basal ration for these studies was composed of yellow corn, soybean oil meal, dehydrated alfalfa meal, minerals (including trace minerals), and vitamins A and D_3. B-Complex vitamins were added to the basal in the later experiments. Protein levels were adjusted to the age and weight of the pigs. In the initial stages of these studies carryover of the animal protein factor by pigs from gestation and lactation affected their performance on experimental growing-fattening rations. The addition of 0.2 to 0.5% of different APF concentrates to the basal produced 19 to 24% faster gains and equalled or surpassed the gains produced by the addition of 2% condensed fish solubles or 6% meat and bonescraps. The tentative vitamin B_{12} requirement for growing-fattening pig appears to lie between 5 and 10 micrograms per pound of total ration. Growth and feed requirement data will be presented.

THE INFLUENCE OF VITAMIN B_{12} CONCENTRATE ON THE GROWTH OF WEANLING PIGS FED ALL PLANT PROTEIN RATIONS ON PASTURE AND IN DRYLOT. R. W. Luecke, W. N. McMillen and F. Thorp, Jr., *Michigan State College.*

Two lots of 7 weanling pigs, each averaging 26 lbs. were fed a corn-soybean basal ration to determine whether B_{12} concentrate would increase gains and efficiency. These pigs were farrowed by gilts which had never been fed any known source of the "animal protein factor." Lot 1 received a ration of corn, 77%; soybean oil meal, 20%; and minerals, 3%. In addition the ration was supplemented with vitamins A and D plus liberal amounts of thiamine, riboflavin, calcium pantothenate, nicotinic acid and pyridoxine. Pigs in lot 2 received the same ration plus a charcoal adsorbed B_{12} concentrate at a level of 0.5%. At the end of 11 weeks the B_{12} pigs made an average gain of 1.5 lbs. per day and averaged 2.66 lbs. of feed per lb. gain. The pigs in lot 1 gained an average of 0.98 lbs. per day and averaged 2.90 lbs. of feed per lb. gain.

In a second experiment two lots of 9 weanling pigs each averaging 26 lbs. were fed the same ration as above. These pigs were farrowed by gilts which had been fed animal protein and were pasture raised. Pigs in lot 3 were fed the same ration as lot 1 and at the end of the sixth week averaged 0.71 lbs. per day. Pigs in lot 4 were fed the same ration as was fed to lot 2 except that the B_{12} concentrate was adsorbed on Fullers earth. At the end of the sixth week these pigs averaged 1.0 lbs. daily gain. In a third series of experiments the effect of B_{12} concentrate on the growth of pigs on pasture will be reported.

CAROTENE REQUIREMENTS OF BEEF CATTLE FOR REPRODUCTION. Louis L. Madsen and Russell E. Davis, *United States Department of Agriculture.*

Reproductive performance of beef cattle is reported from observations made over a period of approximately 12 years. The experiment was carried out at the Beltsville Research Center, Beltsville, Maryland, under dry-lot feeding conditions. The cattle were fed experimental

rations which provided various levels of carotene from 30 to 240 micrograms per kilogram of body weight per day. Three cows failed to have normal calves when on the 30 microgram level. Two cow families receiving the 45 microgram level reproduced successfully, but a number of their calves showed vitamin A deficiency symptoms early in life. One of the cow families receiving the 45 microgram level was carried on to the 4th generation. In the majority of cases reproduction was satisfactory in cows receiving the 60 microgram level of carotene during the first generation, however, a number of the 2nd and 3rd generation cows failed to have normal calves when maintained at the same level of carotene intake. Cows that failed to have normal calves when given 30, 45, or 60 micrograms of carotene reproduced normally when they were given 90 micrograms of carotene or more per kilogram of body weight. Vitamin A analyses by a spectrophotometric procedure indicated that the chances of producing a normal living calf were poor when plasma vitamin A of the dam was below 18 micrograms per 100 ml. at or near the end of the gestation period. Symptoms of vitamin A deficiency in cows, bulls and calves are described in some detail.

THE EFFECT OF LIBERAL B-VITAMIN SUPPLEMENTATION ON GROWTH OF WEANLING PIGS FED RATIONS CONTAINING A VARIETY OF FEEDSTUFFS. W. N. McMillen, R. W. Luecke, and F. Thorp, Jr., *Michigan State College.*

Weanling 24-pound pigs were self-fed a basal ration of corn, expeller soybean meal, meat scraps, alfalfa meal and complex mineral mixture in two feeding trials on concrete floors. The control pigs on the basal ration gained only 0.66 and 0.63 pound daily for nine and ten weeks respectively and showed symptoms of deficiency. Calcium pantothenate alone, or calcium pantothenate and riboflavin, or calcium pantothenate and nicotinic acid when added to the basal ration did not significantly increase growth rate and prevent deficiency symptoms. Calcium pantothenate, riboflavin and nicotinic acid brought about a significant increase in daily gain in both trials (the pigs averaged 1.0 pound per day), prevented the occurrence of deficiency symptoms, and reduced the feed required per unit of gain 22 and 25 percent. In both trials supplements of thiamine, pyridoxine and choline failed to further increase gains or lower the feed requirement. In one trial vitamin B_{12} concentrate also failed to increase gains and efficiency above the increase due to the supplement of pantothenic acid, nicotinic acid and riboflavin. It is concluded that the rations used were deficient in pantothenic acid, nicotinic acid and riboflavin under the conditions of these trials and that liberal supplementation of these vitamins overcame the deficiency.

PRELIMINARY STUDIES ON THE SODIUM AND CHLORINE REQUIREMENT OF PIGS. J. H. Meyer, R. H. Grummer, R. R. Grunert, P. H. Phillips, and G. Bohstedt, *University of Wisconsin.*

This study includes work with natural and purified rations. Two different experiments were conducted with a ration of corn, linseed meal, wheat middlings, and calcium carbonate, and which contained 0.01 to 0.05% sodium and 0.06 to 0.09% chlorine. Salt was added at the following levels: 1) 0.00%, 2) 0.25%, 3) 0.50%, 4) 0.75%, 5) free choice. Essentially there was no difference between the lots in gains or in efficiency of feed utilization. A balance study was made with 4 groups of pigs on a purified ration containing 0.005% sodium and 0.03% chlorine. The lots were as follows: 1) low sodium chloride, 2) low chlorine, 3) low sodium, 4) 0.50% sodium chloride. The average daily gains were 0.49, 0.85, 0.48, and 1.15 pounds and the pounds of feed required for a pound of gain were 4.11, 2.81, 4.12, and 1.93 respectively. Analyses were made for sodium and potassium on muscle, liver, heart, and blood plasma of the pigs in the various groups. Further data will be presented on the intake, excretion, and retention of sodium, chlorine, and potassium.

THE RIBOFLAVIN REQUIREMENTS OF GROWING PIGS AT TWO ENVIRONMENTAL TEMPERATURES. H. H. Mitchell, B. C. Johnson, and T. S. Hamilton, *University of Illinois.*

Pigs weighing 100 to 260 lbs. receiving a constant diet were subjected alternately to an environment of 85° F. and of 42° F. for at least 4 weeks at each temperature. For each of 12

pigs, the larger amount of riboflavin was excreted in the urine at the higher temperature, indicating a smaller requirement at this temperature. Younger pigs in groups of 8 were placed upon a ration containing 0.2 to 0.3 mg. of riboflavin per kgm. with graded supplemental doses ranging from 0.5 to 5.0 mg. per kgm. of feed. They were placed first in one environment and then in another with food intake controlled. Adequacy of the riboflavin intake was judged by rate of body weight gain, appearance and behavior of the pig, appetite and absence of vomiting and diarrhea, blood morphology and post mortem findings. At 85° F., 1.2 mg. of riboflavin per kgm. of feed proved adequate, while 0.7 mg. was definitely inadequate. At 42° F., 1.3 mg. of riboflavin per kgm. of feed was definitely inadequate, and the adequacy of 1.8 mg. was doubtful according to the blood picture. An inadequate riboflavin intake was associated with an increased concentration of polymorphonuclear leucocytes in the blood and a decreased concentration of lymphocytes. There were no consistent differences in the hemoglobin concentration or in the erythrocyte counts of pigs on adequate and inadequate levels of riboflavin.

THE EFFECT OF A HIGH LEVEL OF METHIONINE ON THE CHOLINE REQUIREMENT OF THE BABY PIG. R. O. Nesheim, J. L. Krider, B. C. Johnson, *University of Illinois*

Previous work at the Illinois Station showed that the choline requirement of the baby pig was approximately 0.1% of the dry matter of the diet when it contained 0.8% methionine. Twelve three day old Duroc pigs were fed a "synthetic milk" (13.8% solids) composed of 28.1% vitamin-free casein, 0.8% dl-methionine, 36.4% celerose, 5.8% minerals and 28.9% lard plus all vitamins except choline. Liver extract was injected at the rate of 0.1 ml. per pig daily. The basal diet contained 1.6% methionine. The paired feeding technique was used. One pig of each pair received the basal diet, the other the basal diet plus 0.1% choline. The pigs on the basal diet averaged 46.7 pounds while those receiving 0.1% choline averaged 46.5 pounds at the end of eight weeks. All pigs were extremely thrifty and no external differences were observed. Histological examination of the livers and kidneys showed all to be normal. The baby pig does not require dietary choline when the ration contains 1.6% methionine.

THE EFFECT OF VITAMIN A FROM PRENATAL STORAGE AND FROM INGESTION OF COLOSTRUM ON THE NEONATAL DAIRY CALF. L. Nezvesky, H. D. Eaton, R. E. Johnson, L. D. Matterson, C. I. Bliss, and A. A. Spielman, *University of Connecticut and Storrs (Conn.) Agricultural Expt. Station.*

The effect of vitamin A from prenatal storage and from ingestion of colostrum was studied from birth to 4 wks. of age with 24 dairy calves. Sixty days prior to parturition, dams were divided into 2 groups. One group was fed a basal ration of 1 lb. of U.S. No. 2 alfalfa hay, 3 lbs. of corn silage, and 1 lb. of grain, per 100 pounds liveweight. The other group received the same basal ration plus 1 million U.S.P. units of vitamin A daily for 30 days prepartum. The calves from the 2 groups of cows were subdivided so that one-half received colostrum from dams fed the basal ration and the other received colostrum from the dams fed the basal ration plus vitamin A supplement. Blood samples were drawn from each calf at birth, and before the 2nd, 3rd, 5th, 7th, and 10th feedings, and 7, 10, 14, 21, and at 28 days of age. The criteria studied were total blood Hb, plasma and liver carotene and vitamin A, whole blood and plasma ascorbic acid, fecal pH and dry matter, incidence of scours, and liveweight. Calves from dams fed vitamin A prepartum had significantly greater ($P<0.05$) blood plasma levels of vitamin A at birth than did calves from basal dams. The feeding of colostrum from dams fed vitamin A supplements resulted in significantly higher average blood levels ($P<0.01$) of vitamin A for the experimental period than did the basal colostrum. Both prenatal storage and ingestion of colostrum due to vitamin A supplementation resulted in significant increases ($P<0.05$ for dams and $P<0.05$ for colostrum) in liver storage of vitamin A at 4 wks. of age. The remaining criteria did not appear to be affected by treatment.

RELATION OF VITAMIN A LEVELS IN SOW'S BLOOD TO THAT IN HER COLOSTRUM AND IN BLOOD AND LIVERS OF HER NEW-BORN PIGS: D. B. Parrish, C. E. Aubel, J. D. Wheat, and J. S. Hughes, *Kansas State College.*

The concentrations of vitamin A in blood serum obtained from 14 different sows at time

of farrowing were compared with the concentrations of this vitamin in colostrum (pre-nursing sample) and in blood serum and livers of their new-born and 5-day-old pigs. While a high correlation was not obtained in any of the comparisons, there was a tendency for the vitamin A levels in colostrum and in blood serum of both new-born and 5-day-old pigs to reflect the vitamin A levels in the sow's blood at time of farrowing. There seemed to be little relationship between vitamin A levels of sow's blood and that of the livers of new-born and 5-day-old pigs. The levels of vitamin A in blood serum and in livers of 5-day-old pigs showed some relationship to those of the colostrum produced by the respective sows at time of farrowing. Relationships between several other factors will be discussed.

THE EFFECT OF THYROPROTEIN ON GROWTH AND CARCASS COMPOSITION OF SWINE. T. W. Perry, W. M. Beeson, and F. N. Andrews. *Purdue University Agricultural Experiment Station.*

Three different levels of thyroprotein were fed to 40 head of purebred Duroc hogs to determine its effect on growth and on the chemical composition of the carcasses produced. The pigs were started at an average weight of 42 pounds and fed a basal ration composed of corn 69 percent, wheat 20 percent, Purdue Supplement No. V 10 percent, and minerals 1 percent. Thyroprotein was mixed in the basal ration at levels of 0.0088 percent, 0.0132 percent, and 0.0176 percent. The pigs which received the three levels of thyroprotein gained an average of 32, 40, and 32 pounds more, respectively ($P<0.05$) in the 119 day post-weaning period and required less feed per unit of gain than the controls. All animals were slaughtered at the end of the 119 day feeding period and the carcasses of the animals from the control group and those of the animals from the fastest gaining group (0.0132 percent thyroprotein) were saved for chemical analysis. The carcasses of the animals from the 0.0132 percent thyroprotein-fed group contained a significantly greater ($P<0.05$) percentage of fat and significantly smaller ($P<0.05$) percentage of moisture, ash, and protein than did those from the animals of the control group. When the differences were measured statistically by covariance to adjust for the difference in liveweight between the two groups, however, there were no significant differences between them in moisture, ash, protein or fat content.

EFFECT OF RATION ON NIACIN AND RIBOFLAVIN LEVELS IN THE BLOOD AND MILK OF SHEEP. A. L. Pope, M. Moinuddin, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

Four groups of 10 ewes each were fed the following ration from the beginning of pregnancy: Lot I, Basal or low protein; Lot II, Basal plus a mineral mixture consisting of $CuSO_4$, $CoSO_4$, $FeSO_4$, $MnSO_4$, KI and bonemeal; Lot III, Basal + protein (soybean oil meal); Lot IV, Basal plus minerals and protein. The ewes' blood was analyzed at parturition and again 6 weeks later. In addition to the colostral milk, 5-day, 10-day and 6-week milkings were analyzed. The lambs' blood was analyzed at birth, 24 hours, 48 hours, 5 days, 10 days and 6 weeks of age. The riboflavin data show that there was no significant effect of ration on the riboflavin content of the ewes' blood, the ewes' milk or the blood of the lambs. The riboflavin level of the ewes' blood decreased approximately 50% from parturition to the 6 weeks postpartum bleeding. There was no correlation between the milk riboflavin level and the blood level of the lamb or lambs. Even though the colostrum was considerably higher than the normal milk in riboflavin, the riboflavin blood levels of the lambs decreased until the 5th day of age, when they became relatively constant. Likewise, the niacin blood values of the lambs also decreased as the lambs grew older. The niacin blood levels of the ewes decreased slightly following parturition. In contrast to riboflavin the niacin concentration in the colostrum was only about one-third that of normal milk. There appeared to be some effect of ration on the niacin blood level of the ewes.

THE EFFECT OF PHOSPHORUS DEFICIENCY ON BLOOD PLASMA CAROTENE. O. B. Ross and W. D. Gallup, *Oklahoma A. & M. College.*

Vitamin A studies with beef cattle on phosphorus deficient rations have indicated an

inverse relationship between the level of plasma inorganic phosphorus and plasma carotene. Cattle with abnormally low plasma-phosphorus levels have been observed to have higher plasma-carotene levels than cattle with normal or above normal levels of plasma phosphorus. The cattle involved were cows, heifers and calves managed under range conditions in a phosphorus deficient area of Oklahoma. One lot of each age group received salt as the only mineral supplement while corresponding groups received salt and dicalcium phosphate. Blood analyses were made at 56 day intervals. The cows in the phosphorus supplemented lot have quite consistently maintained plasma-phosphorus levels well above 4 mg. per 100 ml. while at no time during the last 23 months has the average plasma phosphorus of the cows in the unsupplemented lot reached this level. The level of plasma carotene, on the other hand, has ranged from 1 to 40 percent and averaged 20 percent higher in the unsupplemented lot than in the supplemented lot. The heifers in the supplemented and unsupplemented lots have responded in a similar manner. On 12 of the 16 bleeding dates the supplemented lot had higher plasma-phosphorus levels and on 10 of these dates had from 2 to 86 percent higher levels of plasma carotene than those in the unsupplemented lot. Calves showed essentially the same picture. A duplicate experiment conducted in an area where phosphorus deficiency is only borderline, has yielded similar though less consistent results.

ACUTE UREMIA OF SUCKLING RATS BORN TO MOTHERS ON RATIONS DEVOID OF ANIMAL PROTEIN. M. O. Schultze and Harlyn O. Halvorson, *University of Minnesota.*

A very high incidence of early mortality has been observed among young rats born to mothers fed two types of rations: (1) a purified ration containing 24% protein as soybean sodium proteinate and supplemented with DL methionine plus all available fat soluble and B vitamins except vitamin B_{12}; (2) mixtures of ground yellow corn, soybean meal and alfalfa meal containing up to 22 percent protein, supplemented with salts, vitamins A and D, and, in some cases, DL methionine and all available B vitamins except vitamin B_{12}. In spite of excellent lactation by the mothers, several or all young in many litters, although appearing normal at birth, died 24–48 hours after birth with symptoms of acute dyspnea and cyanosis. The blood of these rats with acute symptoms contained about 150 mg. "urea" per 100 ml. as determined by the method of Archibald (J. Biol. Chem. 157, 507 (1945)) 24–48 hours after birth and over 200 mg. "urea" per 100 ml. if they survived more than 48 hours. Acute "uremia" of this type has never been observed in young born to mothers on the same rations supplemented with 3% condensed fish solubles or 2% liver extract (Wilson 1:20) or on highly purified rations containing casein. A transient rise of "bloodurea" from about 30 mg. per 100 ml. at birth to about 60 mg. has been observed during the first few days of life in normal young rats from mothers fed rations containing casein, liver extract or fish solubles. The specificity of the method of urea analysis when applied to severely "uremic" blood requires further study.

QUANTITATIVE DL-TRYPTOPHAN REQUIREMENT OF THE WEANLING PIG. D. C. Shelton, W. M. Beeson, and E. T. Mertz, *Purdue Agricultural Experiment Station.*

In a previous experiment, 0.4% DL-tryptophan was added to a typytophan-deficient, purified ration to supply adequate tryptophan for weanling pigs. To test the validity of this level and to establish the quantitative tryptophan requirement of the weanling pig, 10 Duroc pigs averaging 31 pounds were divided into five lots of two pigs each. Lot I was placed on a basal ration which contained only 0.01% tryptophan and consisted of zein 16.0%, gelatin 10.0%, dextrose 34.3%, dextrin 25.0%, mineral mixture 5.2%, lard 5.0%, celluflour 2.0%, liver extract 0.5%, DL-methionine 0.5%, DL-lysine HCl 1.3% and L-histidine HCl 0.2%. Levels of 0.1, 0.2, 0.3, and 0.4% DL-tryptophan were added to the basal ration of lots II, III, IV and V, respectively, replacing an equivalent amount of dextrose. The animals in lot I lost an average of 0.1 pound per day for the 28-day experimental period and showed all the tryptophan-deficiency symptoms noted previously. The animals in lot II, receiving 0.1% DL-tryptophan, gained 0.47 pound per day. The animals in lot III, receiving 0.2% DL-tryptophan, grew at a much faster rate (1.33 lb./day) and with greater feed efficiency than did those of lots I and

II. There were no significant differences in weight gains or feed efficiency between lots III, IV, and V, (0.2, 0.3, and 0.4% DL-tryptophan, respectively). Likewise, the gains observed on the 0.2% level are comparable to results obtained with weanling pigs on well-balanced natural grain rations. The level of DL-tryptophan required for optimum growth of weanling pigs is tentatively set at 0.2% of the diet.

EFFECT OF GRINDING ON THE UTILIZATION OF MILO GRAIN BY STEER CALVES. Ed. F. Smith, A. D. Weber, and D. B. Parrish. *Kansas State College.*

Previous experiments conducted at this station have shown that Wheatland, Westland and Colby milo, and Blackhull kafir should be ground when fed to fattening cattle. Data are lacking, however, with reference to the degree of fineness to which these grains should be ground. A digestion trial and feedlot trial were conducted to obtain information on this point. For the digestion trial twelve steers were allotted into three lots of four steers each. Atlas silage, cottonseed meal, and milo grain were fed in all lots. Whole grain was fed to lot 1, coarsely ground grain to lot 2, and finely ground grain to lot 3. The coefficients of digestibility of the dry matter, crude protein, ether extract and nitrogen free extract were highest for the steers fed finely ground milo grain and lowest for those fed whole milo grain. Crude fiber was digested most efficiently by the steers receiving whole milo grain. When finely ground milo grain was compared to coarsely ground milo grain in a feedlot trial, it was found that there was little difference in amount of gain or efficiency of gain between steers fed the two forms of grain, although the steers receiving finely ground milo grain appeared fatter at the close of the trial. The steers fed finely ground milo did not eat their grain as eagerly as did those fed coarsely ground milo grain.

PERFORMANCE OF FARM ANIMALS FED RATIONS COMPOUNDED OF SOME TROPICAL FEEDSTUFFS: COROZO, SESAME AND DESMODIUM MEALS. R. L. Squibb and H. T. Love, *Instituto Agropecuario Nacional, Guatemala, U. S. Dept. of Agriculture.*

Data reported herein and trials in progress indicate that the tropics may contain many valuable animal feedstuffs. This project is to compound and biologically evaluate rations of tropical feedstuffs which exist in quantity or may be economically cultivated. One feeding trial conducted in an area having 171 inches of annual rainfall consisted of 18 Duroc Jersey pigs which were divided into six outcome groups of three pigs per group. All pigs were kept in concrete pens. Each group was randomly assigned a different ration adjusted to a 11½ percent protein content. Corozo palmnut meal (Attalea cohune), sesame, and a corozo-sesame combination were the principal sources of proteins. The pigs averaged 41 pounds at the start of the trial and were fed without change of ration for 110 days. There were no significant differences between the resulting average daily gains of .92, .98 and .91 pounds. Feed efficiency at this protein level was 389, 406, and 400 pounds of feed. Desmodiums are similar to alfalfa in chemical composition and grow abundantly throughout the tropics. A meal made of one species of this genus was compared with tropical and U. S. alfalfa meals in a duplicated biological assay using New Hampshire chicks. These meals were added to a basal diet which produced 100 percent mortality in the control group. All rations except the control produced satisfactory growth with no significant differences observed between the meals. The data indicate that this species of Desmodium may replace alfalfa in the diets of chicks.

SOME EFFECTS OF A LOW ROUGHAGE, HIGH CONCENTRATE RATION ON THE FAT OF COW'S MILK. G. E. Stoddard, N. N. Allen, and W. H. Peterson. *University of Wisconsin.*

Several cows have been fed a ration in which the sole roughage was hay fed at a level of six pounds or less per day. Their concentrate intake was increased to the maximum they would consume, in some cases as much as 45 pounds per day. On this ration, with most of the cows

a very marked decrease in the fat content of the milk occurred. There was no appreciable change in the protein, lactose or ash. A decrease in the Reichert-Meissl Number and an increase in the Iodine Number accompanied the decrease in fat percentage. The test returned to normal when the cows were given normal amounts of hay and concentrate. When acetic acid was given by stomach tube, the fat test returned toward normal, whereas propionic acid seemed to have no effect. Limited observations have indicated an increase in the ratio of propionic to acetic acid in the rumen contents when cows were changed to the low-roughage ration. Bacteriological studies are being carried out by others at this station, and their preliminary observations have indicated definite changes in rumen flora with the administration of these acids. There have been reports in the literature of extremely low fat tests when cows were grazing young oat pasture without supplementary roughage. Similar trials were run at Wisconsin, one with rye and one with oats. No depression of fat test occurred, indicating that the condition of the pasture, possibly as affected by the growing season, may have an important bearing on its effect on the composition of the milk. Limited trials on grinding the hay failed to bring about a reduction in fat test when the hay was fed in normal amounts. Further work on the effect of grinding is planned.

THE VALUE OF CELLULOSE IN A PURIFIED DIET FOR GROWING AND FATTENING PIGS. H. S. Teague and L. E. Hanson, *Nebraska Agricultural Experiment Station.*

Twenty-four pigs were used in three experiments to study the effects of replacing portions of the starch in a purified diet, with the cellulose product "Ruffex." The basal diet consisted of 70% corn starch, 15% casein, 6% Brewers' yeast, 6% mineral mixture, and 3% lard. The mixture was changed to 73% starch and 12% casein when fed to animals heavier than 100 pounds. "Ruffex" replaced starch at levels of 2.5, 5.0, 10.0, 15.0 and 20.0% in the various experiments. Cod-liver oil supplied vitamins A and D. The pigs were penned and fed individually. Both the live weight increase and the feed required per pound of gain of the pigs fed 2.5, 5.0, or 10.0% of "Ruffex" were very similar to that of the control animals. The 15.0 and 20.0% levels had a depressing effect on rate of gain and feed utilization. From digestion studies it was observed that the crude fiber, of the "Ruffex"-containing diets was poorly digested at all levels tested (5.0, 15.0 and 20.0%). "Ruffex" had a depressing effect on the apparent digestibility of the protein, nitrogen-free extract and ether extract fractions of the diet. Carcass studies of pigs slaughtered at 100 pounds revealed no marked differences which could be attributed to the diets fed.

VARIATIONS IN PLASMA VITAMIN A CONCENTRATIONS AFFECTED BY DIETARY REGIME OTHER THAN VITAMIN A INTAKE, J. W. Thomas, W. C. Jacobson, and E. G. Whitby, *United States Department of Agriculture.*

It was observed that, contrary to expectations, the plasma vitamin A concentration—determined by modified Kimble method—of some calves increased when they were changed to a ration containing no vitamin A or carotene. The following experiments were designed to study this unexpected result. Calves on whole milk and grain were given 140,000 I. U. of vitamin A daily for 7 days. One week later skim milk replaced the whole milk. Ten calves under 90 days of age were used in 29 such trials. The plasma vitamin A levels increased in 93% (27) of the trials. The average increase of 4.1μg. per 100 ml. persisted for 5 to 18 days. When the calves were over 90 days of age the increase occurred less frequently. Seven trials were made on 7 calves in which the dietary change was from whole milk to a homogenized skim milk—4% lard mixture. In all cases the plasma vitamin A concentration remained relatively unchanged during the following 7 days. In 4 cases skim milk was then substituted for the lard-skim-milk mixture. An increase in plasma vitamin A concentration occurred in all cases, ranging from 5 to 15 μg./100 ml. Therefore in these experiments the simultaneous elimination of butterfat, vitamin A, and carotene from the calves' diet resulted in an increase in the plasma vitamin A concentration. Merely the elimination of carotene and vitamin A (lard substituted for butter-

fat) did not change the plasma vitamin A concentration whereas elimination of fat (lard) resulted in a marked increase.

A STUDY OF NUTRITIONAL ENTERITIS IN PIGS. Frank Thorp, Jr., R. W. Luecke, W. N. McMillen, H. W. Dunne and M. L. Gray, *Michigan State College.*

A detailed study of 80 cases of nutritional enteritis in pigs obtained from 11 different farms in Michigan was made. The results of this study indicate that outbreaks of a certain type of enteritis in weanling pigs raised on farms were due to nutritional deficiencies. This type of enteritis was associated with poor feeding conditions and management. The rations were low in protein and made up largely of cereal grains. The daily urinary excretions of N'methylnicotinamide, niacin, pantothenic acid, riboflavin and thiamine were determined for most of the pigs. The results indicated that the pigs were deficient in niacin, pantothenic acid and possibly riboflavin. The interpretation of the thiamine excretion data must await further investigation. Since the appetities of the deficient pigs were very poor, a solution of thiamine, riboflavin, niacin, calcium pantothenate and pyridoxine in distilled water was given intraperitoneally. Two rations containing 23 percent crude protein and 19 percent crude protein respectively were supplemented with B vitamins, A and D vitamins, 3 percent mineral and fed until the pigs reached a weight of 60 pounds. The pigs showed an average daily gain of 0.71 to 1.21 pounds. The deficient pigs showed varying degrees of emaciation and diarrhea.

VITAMIN B_{12} REQUIREMENTS OF SWINE DURING GESTATION AND LACTATION. R. L. Vohs, D. V. Catron, and C. C. Culbertson, *Iowa Agricultural Experiment Station.*

The purpose of this experiment was to determine the vitamin B_{12} requirement for sows during the gestation and lactation periods. Twenty-four gilts, from sows fed all-plant rations during gestation and lactation, were equally allotted at 54 pounds into 4 concrete drylots. They were fed an all-plant basal ration to which was added 0, 5, 10 and 15 micrograms of vitamin B_{12} per pound of total ration. At the beginning of the gestation-lactation experiment, they were moved to dirt drylots. Each group was continued on the same vitamin B_{12} level as fed during the growing-fattening period. The gestation-lactation basal ration, containing 16% protein, was composed of ground yellow corn, soybean oil meal, dehydrated alfalfa meal, minerals (including trace minerals), vitamins A, D_2, riboflavin, thiamin, niacin, pantothenic acid, pyridoxine, choline and folic acid. Criteria for evaluation of nutritional adequacy of each treatment, such as litter size, individual pig weights, condition of pigs at birth, hemoglobin readings, vitamin B_{12} concentrations of sows milk, will be reported.

THE INFLUENCE OF PREPARTUM COBALT SUPPLEMENTATION ON THE COBALT CONTENT OF NEWBORN-CALF TISSUES. G. M. Ward, E. J. Benne, H. D. Webster, C. W. Duncan and C. F. Huffman, *Michigan State College.*

Neonatal calves from five dams supplemented for periods ranging from 21 to 120 days with cobaltous sulfate and from three control dams were sacrificed without having ingested colostrum. The rate of supplementation was one gram elemental cobalt per 1000 pounds body weight per day. The basal ration consisted of late-cut Bromegrass hay and ground corn. Supplemental cobaltous sulfate was mixed with the ground corn before feeding. The calves were killed by exsanguination. Examination of the carcasses showed no significant gross or microscopic lesions. Samples of various tissues were taken from each calf, as well as a colostrum sample from each cow, for cobalt analysis. The mean tissue cobalt contents of the control calves ranged from 0.10 to 0.22 p.p.m. dry matter with the exceptions of skin and hair which was 1.01 p.p.m. and urine which was 0.36 p.p.m. The mean-fold increases of tissue cobalt content of calves from cobalt supplemented dams over those from control dams were: urine, 140; kidney, 51; liver, 45; small intestine, 17; thyroid, 16; spleen, 15; pancreas, 14; heart, 13; thymus, 11; blood, 10; leg muscle, 4; and loin muscle, 2. The cobalt content of skin and hair was only

slightly increased in the supplemented group. Urine, liver and kidney, in descending order, contained the greatest concentration of cobalt on a dry matter basis. The cobalt content of the colostrum was increased approximately 100 fold by supplementation.

THE EFFECT OF CERTAIN SUPPLEMENTS UPON GROWTH, REPRODUCTION AND LACTATION OF RATS FED PARTIALLY PURIFIED SWINE RATIONS. A. B. Watts, O. B. Ross, R. W. MacVicar and C. K. Whitehair, *Oklahoma A. & M. College.*

The reproduction and lactation performance of female rats was studied by feeding a basal ration composed of corn and vitamin-free test casein supplemented with all the known B-complex vitamins, cod liver oil, and minerals. Supplements tested included Wilson's 1:20 liver concentrate powder, Merck's APF concentrate, and a commercial crude carotene extract of alfalfa. The percent of young born that were alive at 48 hours and the percent of young weaned of those given the female to raise, respectively, for the various groups were: Basal, 92 and 100: basal plus liver concentrate powder, 97 and 98; basal plus APF concentrate, 91 and 93; basal plus crude carotene concentrate 96 and 96. The average weaning weights of the young for the respective rations were; 34.3 gm, 43.2 gm, 42.2 gm, and 40.0 gm. The difference between the weaning weights of the basal fed lot and the lots fed the various supplements was statistically significant but the differences in weaning weights among the supplement fed lots were not significant. A basal ration composed of soybean oil meal, corn, methionine, all known B-complex vitamins, minerals, and cod liver oil was employed in a second study. Liver concentrate powder and APF concentrate were tested with the soybean oil meal basal ration. Statistically significant differences in mortality at 48 hours, number of young weaned of those given the female to raise on in weaning weight were not observed among the lots.

AN IMPROVED METHOD FOR THE DETERMINATION OF CRUDE FIBER. Robert A. Wilcox and Alvin L. Moxon, *South Dakota Agricultural Experiment Station.*

An improved method for the determination of crude fiber has been developed which is a better measure of the digestion resistant portion of feeds than the A.O.A.C. crude fiber procedure. The alkali treatment in the A.O.A.C. procedure removes up to 85 percent of the lignin from the crude fiber of some roughages. The N.F.E. fraction is increased by the amount of lignin that goes into solution resulting in high values with low digestibility coefficients. The new procedure involves an overnight digestion of the moisture and fat free samples with pepsin in .1 percent hydrochloric acid. The residue is filtered, washed with hot water and then boiled in a 5 percent acetic acid solution for 30 minutes. The residue is filtered into a Gooch crucible prepared with an asbestos mat, washed, dried and the loss in weight on ashing calculated as crude fiber. The A.O.A.C. method and this method were compared with respect to the digestibility of crude fiber and N.F.E. fractions in digestion trials on steers. This method was shown to retain most of the cellulose and lignin in a single fraction and the N.F.E. resulting from this method was shown to have much higher digestibility coefficients than the N.F.E. as determined by the A.O.A.C. procedure.

Pasture and Range Section

O. Burr Ross, *Chairman*

WINTERING, PASTURING AND FATTENING STEERS. G. A. Branaman and C. M. Harrison, *Michigan State College.*

Steers have been wintered on two different planes of nutrition during the last five years, and they have all gone to pasture in the spring. The last two lots of 12 each have just been marketed as 2-year olds. The aim has been to finish each lot as Top-Good to Choice steers. In previous years the cattle were finished as yearlings. Treatment before starting experiments and degree of fleshing has influenced rapidity and cost of gains markedly both on winter rations

and on pasture. Very thin 390 pound calves that had received hay only for several weeks gained 1.73 pounds daily on 2 pounds of corn with mixed hay. Others weighing 441 pounds and rather fleshy gained 0.95 pound on the same ration. Regardless of the method of pasture management, the brome and alfalfa pasture, lighter and thinner steers gained most rapidly. Pasture gains have been greatest during the first 60 days. Average results for three years showed most profit per steer when grazed 90 to 120 days before fattening, if selling on a steady market on the basis of dressing percentages. Grain feeding from the start of pasturing was least profitable and 60 days pasturing was intermediate. Pasturing of yearling cattle influences the time period necessary to bring the animals to a desirable market finish. A drop in price level of about $1 from September to January would equalize the two extremes. More than 10 bushels of corn may be saved by maximum use of pasture, especially with steers lightly wintered.

BEEF CATTLE PASTURES IN THE COTTON AREAS OF LOUISIANA. C. I. Bray, C. B. Singletary and W. E. Monroe, *Louisiana State Experiment Station.*

In 1940 the Louisiana legislature appropriated funds for beef cattle pasture work on lands unsuited to cotton production in the hill sections of the state. Projects were set up in 10 areas including eroded hill lands, cut-over lands and wet black lands unsuited to cultivation. Production on improved pasture has varied from 185 lbs. of beef per acre on the poorest lands to 530 lbs. on the heavy black lands. The most satisfactory pastures have been made where both lime and fertilizers were applied. Recommended applications are one to two tons of lime per acre, with initial applications of 400 to 500 lbs. complete fertilizer and annual applications of 200 to 300 lbs. complete fertilizer. Unfertilized pastures have been unprofitable except on the alluvial lands. In one test the yield per acre on unfertilized land was 11 pounds per acre compared to 258 pounds on similar land with lime and fertilizer. Near the North Louisiana Experiment Station at Calhoun, 15 acres of improved pasture established on an abandoned hill-side in 1942 produced in 1949 to August 10, 387 lbs. beef per acre. Cotton in the same area averaging ½ bale per acre produces a net profit per year of approximately $20. A blood test made on a small number of cows showed that cows pastured part time on limed and fertilized pasture averaged 3.66 milligrams phosphorus per 100 cc. blood serum, On unimproved pasture the average was 2.63 milligrams. In one test cows that had been pastured on limed and fertilized land produced an 80% calf crop. Those grazed on fertilized but unlimed pasture produced 65% calves, while cows grazed on unfertilized land produced a 50% calf crop.

FURTHER OBSERVATIONS ON DETERMINATION OF NUTRIENT INTAKE BY GRAZING ANIMALS. R. M. Forbes and W. P. Garrigus, *University of Kentucky.*

A total of 87 individual grazing or digestion trials were made this season with steers and wethers as experimental subjects. Nutrient intakes and digestibilities were calculated, in grazing trials, by the lignin ratio method, and in digestion trials by the lignin ratio and by the conventional methods. Results are in agreement with those previously reported. The influence of forage protein will be shown, and the application of this relationship to determination of nutrient intake by grazing animals will be illustrated.

PHOSPHORUS STUDIES OF RANGE BEEF CATTLE. W. D. Gallup, O. B. Ross, and D. F. Stephens, *Oklahoma A. & M. College.*

Two areas of Oklahoma were selected for a study of the value of phosphorus supplementation for growing beef heifers grazing native grass ranges. One area, located at Wilburton in the Southeast, has an acid soil which contains very little available phosphorus; the other area at Stillwater in the North-Central has a slightly acid soil which is somewhat higher in available phosphorus and is considered to be border line between adequate and deficient. Three lots of weanling Hereford heifers of 10 head each were placed in pastures at each of the two areas. During the grazing season at each area (April through October) Lot 1 had free access to salt as the only mineral supplement; Lot 2 had access to a mineral mixture of 9 parts salt

and 1 part dicalcium phosphate; and lot 3 had access to a mineral mixture of 2 parts salt and 1 part dicalcium phosphate. During the winter months (November through March) all lots were placed in winter trap and fed prairie hay and corn gluten meal. Lot 1, the low-phosphorus lot, received no phosphorus supplement; lot 2 was given dicalcium phosphate in such amounts that the total daily ration supplied approximately 1.5 gm. of phosphorus per 100 lbs. live weigh or about half the estimated requirement; lot 3 was given dicalcium phosphate in amounts which provided for an estimated adequate daily phosphorus intake of 2.5 gm. per 100 lbs. live weight. Complete records were kept on these heifers for a period of 21 months covering two summer grazing seasons and one and one-half winter seasons. The feeding of about 26 pounds of dicalcium phosphate per head at Wilburton during the experiment produced heifers (lot 3) which were 136 pounds heavier than those not fed such a mineral supplement (lot 1). The heifers of lot 2 which were fed approximately one-half the estimated phosphorus requirement gained 107 pounds more than heifers fed no phosphorus supplement (lot 1). In general, the blood-plasma phosphorus level closely parallelled the growth performance in each lot. Very little difference in gain was observed among the three lots of growing heifers at Stillwater. The correlation between plasma phosphorus values and total gain was less marked at Stillwater than at Wilburton.

COMPARISONS OF PASTURES AND SUPPLEMENTS FOR GROWING-FATTENING PIGS. J. L. Krider and S. W. Terrill, *University of Illinois.*

Growing-fattening pigs, weighing 40 to 50 lb. initially and self-fed to 200 lb., required 6% more concentrates per 100 lb. gain on bromegrass than on alfalfa pasture. The pigs on alfalfa psature required 33% less protein supplement and 13% less minerals per unit of gain and reached the final weight one week earlier. Alfalfa-bromegrass pasture was fully equal to alfalfa pasture for self-fed pigs. On similar pastures, the rates of gain between groups did not differ significantly when the following supplemental mixtures were self-fed free-choice with shelled corn and minerals: (a) 1 tankage, 1 expeller soybean meal; (b) 2 expeller soybean meal, 1 alfalfa meal; (c) 1 expeller soybean meal, 2 ground oats; (d) 1 meat and bone scraps, 1 expeller soybean meal; (e) 1 expeller soybean meal, 1 dried corn distillers' solubles; (f) 1 meat and bone scraps, 1 dried corn distillers' solubles; and (g) (f) plus 1 soybean meal. Pigs self-fed pelletted supplement free-choice on pasture ate 8.4 lb. more supplement and 17 lb. less shelled corn per 100 lb. of gain than pigs fed meal supplement. Exposing self-fed pigs on alfalfa-bromegrass pasture to night lights for two intervals of one hour each had no significant effect on performance in comparison to controls fed the same ration. When expeller soybean meal was self-fed free-choice, the pigs ate almost twice as much as those hand-fed only enough soybean meal (½ lb. per head daily) to balance the protein content of the ration without significantly increasing either the rate or the economy of gain. In one test solvent soybean meal was more palatable and was consumed in larger quantity than expeller soybean meal when each was self-fed free-choice to pigs receiving shelled corn and minerals.

RESPONSE OF CATTLE ON PASTURE TO VARIOUS PHOSPHATE FERTILIZERS. Harold E. Henderson, George K. Davis, and W. G. Kirk, *University of Florida Agricultural Experiment Station.*

Response in terms of production, reproduction and blood changes has been followed in cattle maintained on Pangola grass (*Digitaria decumbens*) pastures on a year around basis. The pastures were fertilized identically except for phosphorus, which was applied by superphosphate plus lime, or by raw rock phosphate, with the amounts kept at a level designed to supply an equal amount of available phosphate per acre. Blood phosphorus levels indicated that adequate phosphorus was supplied by the grass to the animals on phosphate fertilized pasture. Those on the control pastures showed some indication of deficiency. The principal differences attributed to the different phosphate amendments have been in the yields of forage and resultant carrying capacity, but marked differences in phosphorus content of the grass have been observed. On the acid sandy soils, rock phosphate gave as good results during the two years of

this experiment as did the more available superphosphate. Considerable variation in the consumption of secondary mineral elements was noted on the pastures fertilized with the different phosphate sources.

A NEW INDICATOR METHOD FOR THE DETERMINATION OF DIGESTIBILITY AND CONSUMPTION OF FORAGES BY RUMINANTS.

J. T. Ried, P. J. Woolfolk, C. R. Richards, J. K. Loosli, K. L. Turk, J. I. Miller and R. E. Blaser, *Cornell University.*

A study was made to determine whether forages contain chromogenic substances which are indigestible, completely recoverable in the feces and, therefore, adaptable to use as a reference material for the indirect measurement of digestibility and consumption of forages by ruminants. The examination within the visible spectral range of acetone extracts of various forages and of the feces voided by animals consuming the respective forages revealed that some chromogen(s) absorbing light in the vicinity of 406 mμ is completely recoverable in the feces. Since the identity of the responsible chromogen(s) is not known, a spectrophotometer (Beckman DU model) was calibrated at 406 mμ using graded concentrations of Na_2CrO_4 solutions. This allowed the quantitation of the chromogen(s) content of the acetone extracts in terms of a known chromogen (Na_2CrO_4). As a result of these findings a method for the estimation of forage digestibility and consumption was devised consisting of the following procedures: (1) Extraction of chromogenic substance(s) from a known quantity of forage and of corresponding feces with 85% acetone, (2) measurement of chromogen(s) content of the extracts at 406 mμ, and (3) calculation of digestibility coefficients and intake of the forage. The validity of the proposed method was established by comparing the results obtained with those derived from conventional digestion trials. The average and range of the percentage of the ingested chromogen(s) recovered in the feces of animals consuming the following forages were: field cured mixed hay (wethers and bull calves), 101.5 (99.9–106.2); barn dried mixed hay (wethers and bull calves), 99.9 (96.2–104.2); oven dried mixed hay (wethers), 99.9 (97.4–102.3); mixed hay crop silage (wethers and bull calves), 99.5 (96.4—102.6); Ladino clover hay (wethers), 100.9 (100.5–101.3) and timothy-mixed pasture grass (steers): vegetative stage, 100.9 (99.2–102.4); boot to early head stage, 102.7 (98.8–105.8) and full bloom stage 100.3 (94.4–103.3).

THE EFFECT OF IMPROVED PASTURES UPON THE MINERAL METABOLISM AND GROWTH OF BEEF STEERS.

O. B. Ross, Horace J. Harper, W. W. Albert and W. D. Gallup, *Oklahoma A. & M. College.*

Badly eroded, worn out land was secured in southeast Oklahoma in 1945 for this study. Four soil types found in the area were fenced to make comparable pastures for fertility and grazing studies. Nine pastures were established. Bermuda grass roots, rye grass and legume mixture were planted in seven of the pastures. The two remaining pastures were planted to weeping love grass and a legume mixture. Two pastures, one on prairie soil and the other on a forested soil received no fertilizer treatment, two pastures received an application of 2 tons of limestone per acre and three received 2 tons of limestone and 150 pounds of superphosphate per acre. Two pastures on forested soil were treated with 200 pounds of 0-14-7 and 2 tons of limestone. In the fall of 1946 sixty choice weanling Hereford steer calves were purchased for the grazing tests and were marketed as three-year-old steers in July, 1949. Steers allotted to the various pastures as calves were grazed in their respective pasture for each of the three grazing seasons and were wintered in a trap on prairie hay and corn gluten meal. Pastures receiving the limestone application produced 20 to 40 percent more total gain than did comparable untreated pastures. Pastures treated with both limestone and super phosphate produced 85 to 89 percent more total gain than comparable untreated pastures. The plasma calcium of steers grazing the various pastures was in general the same for each of the grazing seasons. The plasma-phosphorus level of the steers grazing the various pastures showed very little variation the first two grazing seasons, but during the third grazing season the steers in the phosphate treated pastures had 66 to 103 percent higher plasma-phosphorus levels than steers grazing comparable untreated pastures. The steers grazing the limestone treated pastures had 7 to 32

percent more plasma phosphorus than steers grazing untreated pastures. The ash content of the bones of steers grazing the phosphate treated pastures was from 1 to 2 percent higher than for those grazing the untreated pastures.

THE RELATIVE NUTRITIVE VALUE OF KENTUCKY BLUEGRASS, *POA PRATENSIS* L., TIMOTHY, *PHLEUM PRATENSE*, BROME GRASS, *BROMUS INERMIS* AND ORCHARD GRASS, *DACTYLIS GLOMERATA*. R. W. Swift, R. L. Cowan and R. H. Ingram, *Pennsylvania State College*.

Six replicated plots 45 × 160 ft, of each of the above grasses were established on the college Farm for the purpose of producing these forages under like conditions of soil fertility and rainfall. The grasses were cut at comparable stages of maturity and all were dried under identical conditions in a special hay drier constructed for the purpose. The four grasses, fed to sheep in the course of 81 feeding trials with 11-day collection periods, were evaluated in accord with their content of metabolizable energy, digestible energy, digestible dry matter and total digestible nutrients. Brome grass and Orchard grass were found to be practically identical in energy feeding value and definitely greater than that of Timothy. Kentucky Bluegrass proved to be slightly superior to Brome grass and Orchard grass.

Physiology Section

R. W. Bratton, *Chairman*

THE EFFECTS OF ENVIRONMENTAL TEMPERATURE AND RELATIVE HUMIDITY ON ACCLIMATION OF CATTLE IN THE TROPICS. C. Gaztambide Arrillaga, *University of Puerto Rico*.

The effects of air temperature and humidity on body temperature, respiratory rate, pulse rate, hemoglobin and milk production were studied during two years in Puerto Rico. The cow population studied included the Holstein, Guernsey, Jersey, Ayrshire and Brown Swiss dairy breeds, and the Hereford, Shorthorn, Brahman and native beef breeds. The average air temperature was 85° F. and the relative humidity was 63% for the period studied.

The average body temperature of the five dairy breeds studied was 102.09° F., as compared to 101.5° F. considered to be normal. The respiratory rate for the dairy breeds was 52.7 respirations per minute as compared to 22 respirations per minute considered to be normal. The pulse rate in the dairy breeds studied was 45.9 beats per minute as compared to a normal of 45 beats per minute in cattle. The hemoglobin content in all the dairy breeds studied was 70.7 grams hemoglobin per 100 milligrams of blood (45% hemoglobin). This is low when compared to a normal content of 125 grams hemoglobin per 100 milligrams of blood in a temperate climate (80% hemoglobin). The body temperature of the four beef breeds studied was 102.27° F. The body temperature, respiratory rate and pulse rates of the beef breeds studied were slightly higher than for the dairy breeds. Results indicate that the Brown Swiss and Jersey breeds adapt better to a semitropical environment.

SOME EFFECTS OF TESTOSTERONE PROPIONATE AND THYROPROTEIN IN RAMS. W. G. Black, A. L. Schick, A. L. Pope and L. E. Casida, *University of Wisconsin*.

Four groups of three rams each were studied on the following treatments during the interval from July to September, 1948: A. Control, B. Ten milligrams of testosterone propionate injected subcutaneously daily, C. One gram of thyroprotein per 100 pounds of body weight given orally daily, D. Ten milligrams of testosterone propionate plus one gram of thyroprotein per 100 pounds body weight daily. The control rams gave a progressively shorter reaction time to the artificial vagina as the experiment progressed. There were also decreases in reaction time for the testosterone and testosterone plus thyroprotein groups—less than for the control in the first case, but not different from the control in the second. Those rams receiving thyro-

protein, only developed slower reaction times as the experiment progressed. As compared with the controls the rams treated with testosterone showed a significant increase in semen volume, and decrease in sperm concentration. Total number of sperm were not affected. Treatment with thyroprotein caused a significant loss in weight of the animals and a decrease in concentration of sperm. The changes in volume of semen and in total number of sperm were not significant. Treatment with a combination of testosterone and thyroprotein resulted in a significant weight loss, but less than in the thyroprotein group. There was also an increase in semen volume, but changes in concentration of sperm and total number of sperm were not significant.

SOME EFFECTS OF AMBIENT TEMPERATURE, 0 TO 105° F., ON DAIRY CATTLE. Samuel Brody, H. J. Thompson, H. H. Kibler, and A. C. Ragsdale, *University of Missouri and United States Department of Agriculture.*

There are profound individual differences in the rates with which cows increase water consumption with increasing temperature between 80° and 100° F. (some decrease it, others increase it four-fold). These differences suggest developing heat-tolerant cattle; also keeping cattle cool in hot weather by increasing cold-water consumption (by adding salt to feed?). The optimal temperature for quantity and efficiency of milk production is near 50° F; the critical high temperature, about 80° F; no definite critical low temperature, but feed consumption tended to increase, milk yield to decrease, and fat percentage to increase below freezing. A sudden decline in temperature from 50 to 0° F increased hay consumption 20 to 40 percent and reduced milk yield. Small cows are more sensitive to low temperatures, and large cows to high temperatures. Surprising observations: Between 80 and 100° F. there is a 40 percent decrease in heat production, pulse rate, blood cholesterol; 100 percent increase in blood creatinine; rise in rectal temperature from 105° F. (Jerseys) to 108° F. (Holsteins); rise in surface temperature to 103° F. with rise in ambient temperature to 103° F., when 100 percent of the heat produced is dissipated by vaporization. (Man's surface temperature is 94° F. and rectal temperature normal at 103° F. ambient temperature.) At 103° F. moisture is vaporized at the rate of 200 to 250 gm. per square meter surface, or 2.0 to 2.5 lbs. per 1000 lbs. live weight per hour. Details are presented in Missouri Research Bulletin series on "Environmental Physiology."

THE ABSORPTION OF RADIOACTIVE THYROPROTEIN IN SHEEP AND CATTLE. D. J. Campbell, F. N. Andrews and J. E. Christian. *Purdue University.*

Radioactive thyroprotein was prepared from vitamin-free casein and I_{131} using methods previously described for the preparation of ordinary thyroprotein. The thyroxine content of the iodocasein as determined gravimetrically was 3.1 percent and was found to be 3.06 percent when determined by the isotope dilution technique. The radioactive thyroprotein was administered in solution, intravenously, orally, and through rumen, small intestine and cecal fistulas. In sheep, when administered intravenously, nearly all the radioactivity had disappeared from the blood within 7 hours. The highest peaks of blood radioactivity were obtained following oral or rumen administration about 10 hours following treatment. The activity was greater than following small intestine administration and there was practically no absorption from the cecum. The nature of the activity following absorption in the blood is not completely known. Part was in the form of radicactive thyroxine and part was present as diiodotyrosine and other iodine containing compounds.

ADDITIONAL OBSERVATIONS ON THE NATURE OF REPRODUCTIVE FAILURES IN COWS OF LOW FERTILITY. R. E. Christian, W. H. Fleher and L. E. Casida, *University of Wisconsin and Badgers Breeders' Cooperative.*

This study was conducted on 42 Holstein cows, all of which had been bred at least four times without apparent conception. Only cows that showed no detectable genital abnormalities upon clinical examination were used. The percentage fertilization as found at three days

after breeding was 88.5 and the percentage of cows with normal embryos at 34 days after breeding was 26.7 for an embryonic death rate of 69.8. The comparable figures for the preceding year's work on 104 cows were 66.1, 23.1 and 65.1. There was agreement between this study and that of the previous year in that number of calvings and herd breeding index had appreciable effect upon fertilization rate; and number of calvings, herd size and herd breeding index had appreciable effect upon early embryonic death. There was, however, a failure of agreement on the effect of Bang's disease upon early embryonic death between the two years.

MOTILITY PATTERNS OF THE CECUM OF THE HORSE. P. T. Cupps, and C. E. Howell, *University of California.*

A fistula was established by surgical means in the cecum of a Percheron filly fourteen months of age. Kymographic records of the motility of the organ were taken. Peristaltic waves traveling from the base to the apex with occasional waves traveling in the reverse direction were found. Local contractions were interspersed between the peristaltic waves. Large tonus changes occurred and seemed to be related with movement of ingesta through the digestive tract. The patterns of activity could be modified by changing the kind of feed and feeding method. Drinking large amounts of water modified the pattern of motility extensively. Feed first appeared at the fistula in about one and one-half hours after eating; reached a maximum at three to four hours; then declined until very little was present after six hours. Leakage of ingesta from the fistula was greater when the roughage was alfalfa than when it was oat hay.

STUDIES OF HIGH DIETARY POTASSIUM INTAKES IN RUMINANTS. Geo. Curme, III, H. D. Eaton, L. D. Matterson, C. I. Bliss, C. F. Helmboldt, B. A. Brown, and E. L. Jungherr., *University of Connecticut and Storrs (Conn.) Agricultural Experiment Station.*

The application of potash to soil can result in marked increases in the potassium content and decreases in the calcium content of roughages. To study whether or not this variability in the mineral content of roughage affects ruminants, 2 lots of mixed alfalfa-grass hay, one containing 1.31% K and 1.60% Ca ("normal hay") and another containing 2.73% K and 0.61% Ca ("high K-hay"), were fed to sheep. Three replicates of 4 late spring lambs each were fed for a 12-wk. period as follows: I, "normal hay"; II, "normal hay"+sufficient KCl to make the K intake in the hay equivalent to 4%; III, "high K-hay"; and IV, "high K-hay"+sufficient KCl to make the K intake in the hay equivalent to 4% K. Each lamb was also fed ½ lb. grain daily and hay intakes per animal within replicates equalized. No statistical differences were found in av. weekly whole blood K or serum K and Ca determinations. Four 7-day balance studies run on each replicate during the exp. period resulted in statistically significant increases in the actual and % retention of K due to feeding "high K-hay" and also to feeding supplementary KCl. "Normal hay" alone resulted in greater retention of Ca than "high K-hay" alone or high K-hay+KCl. The addition of KCl to "normal hay" resulted in a decrease in Ca retention. The % retention of Ca was greater in groups III and IV than in group I. Fecal and urinary outgo were also studied. Liveweight determinations, differential blood counts, and gross and histopathological examination of parenchymatous and nervous tissues failed to reveal differences due to treatment.

FERTILITY STUDIES WITH STREPTOMYCIN IN BOVINE SEMEN. H. L. Easterbrooks, P. Heller, W. N. Plastridge, E. L. Jungherr, and F. I. Elliott, *Storrs (Connecticut) Agricultural Experiment Station.*

The purpose of this investigation was to compare the fertility rates of diluted semen with and without the addition of streptomycin, in the routine operation of the Connecticut Artificial Breeding Association. The 60–90 day non-return (N.R.) to first service percentage was utilized as the basis of comparison. Equal parts egg yolk and sodium citrate (3.6%) plus sulfanilamide (0.6%) in sterile water distilled over glass was the standard diluent used through out the study. The split sample technique was applied to every sample of semen shipped from

the Stud over the four-month period covered by this report. By using this method each bull each day served as his own control, half of the semen being diluted with the standard diluent and the other half with the standard diluent containing 100 micrograms of streptomycin in each milliliter of diluted semen. Sixteen different bulls were used in the operation during the course of the study. 2340 cows were inseminated with untreated semen and 2379 with semen containing streptomycin. Results showed a 61.1% N.R. for the control group as compared to a 69.8% N. R. for semen treated with streptomycin. Analysis of N. R. % by ejaculates, by months, by all individual bulls, and by individual bulls used each month of the four month period was statistically significant. Bacteriological studies and field trials to determine the optimum level for streptomycin in diluted bull semen are under study.

THE PRODUCTION OF CYSTS IN NORMAL AND PREGNANT SOWS WITH PREGNANT MARE'S SERUM. J. A. Green and A. V. Nalbandov, *University of Illinois.*

Sows pregnant 35 to 60 days and cycling sows were given a single intramuscular injection of pregnant mare serum gonadotrophin (PMS). The dose ranged from 50 to 100 Cartland-Nelson units per injection. The animals were slaughtered one to eleven days after the injection and the ovaries were examined for gross and histological changes. The effects ranged from no visible macroscopic changes to the formation of cystic follicles. One or two follicles in several pregnant sows were caused to ovulate and eggs were recovered from the oviducts. In all cases the number of ovulations produced was lower than that found in untreated cycling sows and no instances of superovulations were observed. Comparisons between the macro- and microscopic appearance of naturally occurring and PMS-induced cysts will be made and the possible mechanism of cyst formation will be discussed.

INBREEDING AND STRAIN DIFFERENCES IN REPRODUCTIVE PERFORMANCE OF BOARS. E. R. Hauser, C. D. Squiers, G. E. Dickerson and D. T. Mayer, *University of Missouri.*

Boars of three inbred lines, two Poland China (II and VI) and one Hampshire (V), one non-inbred Duroc (D), and their six crosses were castrated at ten day intervals at ages from 125 to 175 days. Testes of 85 boars were studied histologically to determine the stage of spermatogenesis, (scale 0 to 3), and other characteristics of the testes and epididymis. At the average age of 150 days the lines of boars ranked II×VI 2.79, VI×D 2.70, V×D 2.60, VI 2.17, V 2.07, V×VI 2.06, D 2.00, II×V 1.42, II×D 1.40, and II 0.88. Crosses exceeded inbred parents by about 30 percent in body and testes weight, and 21 percent in epididymis size and stage of spermatogenesis. In early testicular growth, the diameter of the seminiferous tubules increases but after sexual maturity, growth of the testes results largely from increased length of tubules as inter-tubular space increased but a small amount. Based on the age at increasing sperm production or age at first fertility of 22 boars the ranking was II×D, VI×D, V×D, V×VI, VI×II, V×II, and II. Variability between groups was significant ranging from 161 to 231 days. There was no difference between boars or lines of boars in fertilization rate after first fertile mating. Thirty-six of 51 gave 100 percent fertilization of eggs recovered. The average for all matings was about 93 percent, or a loss of .8 pigs. Variability in 25 days fertility was largely due to maternal influence and to the genetic constitution of the embryo.

THE HORMONE CONTENT OF NORMAL AND CYSTIC OVARIES OF SWINE. R. L. Hays and A. V. Nalbandov, *University of Illinois.*

The estrogen content of the fluid and the tissue of normal and cystic ovaries was determined. The increase in uterine weight of the castrate, immature rat was used as the assay method. Two types of normally occurring cystic ovaries were distinguished. The first type consisted of 1 to 14 cysts measuring 15 to 56 mm, the second type had 12 to 34 cysts measuring 12 to 21 mm. in diameter. In addition assays were run on fluids and tissues of cysts produced by the injection of pregnant mare's serum (PMS) into pregnant sows. Extracts of fluid and tis-

sue of the cysts of the first type produced uterine weight increases in rats ranging from 20–60% and indicated a low estrogen content. Fluid and tissue from cysts of the second type and from PMS cysts, caused a uterine weight increase of about 600% and indicated a high estrogen content. Sows and gilts with large cysts had typical progesterone type uteri while females with the cysts of the second type had uteri showing estrogen stimulation. The combined theca folliculi and granulosa of normal, non-cystic ovaries, contained much more estrogen per gram than did the follicular fluid or stroma of the ovary.

THE EFFECTS OF SOME CLIMATIC FACTORS ON CERTAIN FUNCTIONS OF SWINE. Hubert Heitman, Jr., E. H. Hughes and C. F. Kelly, *University of California and United States Department of Agriculture.*

Swine of various weights have been kept in a psychrometric room at varying temperatures and relative humidities. Body temperature, and respiratory rate increased with increasing air temperature, whereas pulse rate and feed consumption decreased. The temperature at which the average daily gain and rate of feed consumption were greatest depended on the weight of the animals. An increase in relative humidity at high air temperature distressed the hogs. The effects of cooling by water and the use of increased air motion have been studied. Results of high air temperatures on gestating sows will be presented.

EXPERIMENTAL VITAMIN A DEFICIENCY IN YOUNG DAIRY CATTLE. E. L. Jungherr, C. F. Helmboldt, and H. D. Eaton, *Storrs (Connecticut) Agricultural Experiment Station.*

Two groups of 4 calves each representing the standard dairy breeds, males except one freemartin, aged 53 to 369, average 192 days, received a daily allowance of 4 lbs. grain mixture containing <350γ carotene/lb and beet pulp *ad. lib.* for about 105 days. One calf's ration per group was supplemented with 100,000 I.U. vitamin A from dog fish oil containing 25% crude soybean lecithin. Weekly determination of plasma carotene showed a drop from 172γ% to 9 against those of supplemented controls 139 to 10, and of vitamin A from 25.5 to 3.7 against 21.8 to 38.2. The average final liver storage was 0.45γ carotene and 1.97 vitamin A as against 0.50 carotene and 61.45 vitamin A/gram. The initial and terminal spinal fluid pressures averaged 118 and 304 against 106 and 128 mm., respectively. Weekly hemoglobin and monthly liver biopsy examinations failed to show changes. The animals were sacrificed when showing daily convulsions. One Jersey yearling died after 64 days on the diet. Gross pathologic examinations were essentially negative. Histopathologic examinations revealed: In testes, arrest of epithelial development in seminiferous tubules, primarily at the level of spermatogonia; in pituitary, relative predominance of acidophils and lack of basophils; in thyroid, irregularity in size of follicles and slight epithelial hyperplasia; in kidneys of one animal, small polymorphonuclear tubular casts; in parotid squamous hyperplasia and metaplasia in excretory ducts, often leading to papillomatoid proliferations of the epithelium with cystic or kerato-pearly enclosures. The bovine parotid appears to be the most likely organ to show specific morphologic expressions of A avitaminosis, a point of diagnostic interest.

THE MORPHOLOGY OF THE OVIDUCT OF VIRGIN HEIFERS IN RELATION TO THE ESTROUS CYCLE. Louise Lombard and Banner Bill Morgan, *University of Wisconsin.*

The gross anatomy and histology of the oviducts were studied in 33 clinically normal virgin heifers slaughtered throughout the estrous cycle. The oviduct can be divided into three parts; isthmus, ampulla and infundibulum. The wall consisted of three layers; tunica mucosa, muscularis and serosa. The mucosal ciliated epithelium was pseudostratified columnar throughout the length of the oviduct. Three types of cells were seen in the epithelium; ciliated columnar cells, peg or intercalary cells and spherical cells. The various regions of the oviduct had distinct characteristics primarily in the number of mucosal folds. Complete cellular changes in relation to the estrous cycle were studied. The presence of edema and granules in

the epithelial cells was most pronounced from one day proestrus to two days postestrus. Mucus-like material in the oviduct was more abundant during three to four days postestrus while cytoplasmic projections of the epithelial cells occurred during proestrus. The height of the epithelium during proestrus was 32.6 microns, estrus 45.3 microns, one to five days postestrus 43.8 microns and 26.6 microns during six to fifteen days postestrus.

EFFECTS OF STARVATION IN RATS AND MICE ON THYROID SECRETION RATE AS INDICATED BY UPTAKE OF RADIOACTIVE IODINE AND THIOURACIL ACTION. Joseph Meites, *Michigan State College.*

It is known that starvation in animals results in reduced thyroid activity, as evidenced by a decrease in thyroid weight and histological appearance of atrophy. From a quantitative aspect, the extent of the reduction in thyroid function during any particular degree of starvation remains to be determined. An approach was made to this problem by quantitatively underfeeding rats and mice for various time periods and then injecting them with radioactive I^{131} or thiouracil. A tracer dose of I^{131} was injected into rats at the end of each starvation period, while thiouracil was administered to both mice and rats for 10-day periods. The results indicate that the uptake of radioactive iodine was reduced in the thyroids of the starved as compared to the normally fed rats, but on a 100 gm. body weight basis there was no difference in iodine uptake. Similarly, when underfed and normally fed rats and mice received the same doses of thiouracil by injection, there was less increase in the thyroid weight of the former than in the latter, but similar increases occurred in both groups when computed on a body weight basis. These data suggest that the thyroid secretion rate in underfed rats and mice is reduced in direct proportion to the reduced body weight of these animals.

THE EFFECT OF A COMBINATION OF PENICILLIN AND STREPTOMYCIN IN SEMEN DILUTORS ON THE FERTILITY OF DAIRY BULLS. John P. Mixner, *New Jersey Agricultural Experiment Station.*

Two experiments were conducted to determine the effect of adding both penicillin (1000 units per ml. of diluter of potassium penicillin G-Eli Lilly) and streptomycin (1 mg. per ml. of dilutor of streptomycin calcium chloride complex-Merck) to an egg yolk citrate sulfanilamide dilutor on the fertility of dairy bulls. The first experiment (conducted at New Jersey Cooperative Artificial Breeding Unit No. 1, Inc., Clinton) was run on a split sample basis involving a total of 11 bulls of two breeds, 47 semen samples and 2263 first and second service breedings. The second experiment (conducted at Sussex County Co-operative Breeding Association, Inc., Newton) was a two treatment reversal trial with four collection periods involving a total of 12 bulls of two breeds, 48 semen samples and 801 first and second service breedings. The data in each of the two experiments were evaluated using the analysis of variance technic. The mean fertility values for the two diluters were extremely close and no significant increases or decreases in the fertility levels due to the added antibiotics could be demonstrated.

THE METABOLISM OF THYROXINE. R. A. Monroe and C. W. Turner, *University of Missouri.*

A study utilizing the goiter prevention method in chicks showed that crystalline D, L-thyroxine was about one-half as effective orally as its mono- and disodium salts. It was calculated that the crystalline thyroxine was 20% absorbed, and the salts 45% absorbed. Desiccated thyroid was found to be equally as effective orally as injected. Thyroprotein fed to goats was calculated to be 78–88% absorbed. Of daily injections of 10 mg. of thyroxine over a 10 day period in goats, a calculated maximum of 5% was excreted in the feces. None was excreted in the urine. The rate of disappearance of orally administered thyroxine was measured by its effect on the thyroid weight of thiouracil-treated chicks. It was found that, up to a

point, thyroxine remained longer in the organism with increasing doses. After this point in dosage level no further increase in duration time could be obtained by increasing the dose of thyroxine. The males did not normally catabolize thyroxine as rapidly as did the females. But the males were capable of disposing of an excess of thyroxine as rapidly as the females. Calcium pantothenate hastened the disappearance of thyroxine, while thiamin and niacin had the opposite effect. Vitamin B_{12} was found to be necessary for the normal catabolism of thyroxine. Vitamin A and the other B vitamins were without effect on the disappearance of thyroxine. Thyroprotein fed to hens caused enlargement of the thyroid glands of their chicks.

STORAGE OF JACK SEMEN AND ITS USE IN ARTIFICIAL INSEMINATION. R. L. Murphree, C. S. Hobbs, G. D. Folmar, M. C. Hervey and W. M. Whitaker, *Tennessee Agricultural Experiment Station.*

A study was made of the effects of diluters composed of glucose; combinations of glucose and sodium potassium tartrate; combinations of glucose, sodium potassium tartrate, and egg yolk; and combinations of glucose and egg yolk upon the maintenance of motility, liveability and resistance to cold shock of jack sperm. Examination for motility and percentage alive was made at 24 hour intervals. In all of the samples studied the combination of 5 percent glucose with egg yolk gave superior motility up to 144 hours as compared to less than 24 hours for the undiluted control samples. The glucose-egg yolk diluter was compared with phosphate-egg yolk and citrate-egg yolk diluters and found to give a longer survival time of the sperm. The percent of sperm alive as determined by the fast green-eosin staining technique within 1 hour after collection was not correlated with sperm survival time. Semen diluted at the rate of one part of semen to one part of the diluter (5 parts of 5 percent glucose to 1 part of egg yolk) has been used for artificial insemination of mares. Fertility data on samples stored 24 to 40 hours before insemination will be presented.

FURTHER STUDIES ON TEMPERATURE ADAPTATION IN BABY PIGS. H. W. Newland, W. N. McMillen, Frank Thorp, Jr., and E. P. Reineke, *Michigan State College.*

In continuation of the work reported last year, sows were farrowed under two conditions of environmental temperature; one room at 60° to 70° F., the other at 25° to 30° F. During the first half hour after birth the average drop in body temperature of the pigs born in the warm environment was 3.0°, as compared to an average drop of 8.8° for pigs born in the cold. In 48 hours the pigs in the warm room had reached an almost normal body temperature of 102.0° F., while those in the cold environment averaged only 100.7° F. in the same length of time. Body temperature drop was inversely proportional to birth weight, smaller pigs dropping lower and returning to normal at a slower rate. The blood picture on pigs two to four days old, chilled at 34° F. for three hours, showed a definite drop in blood hematocrit. On 15 pigs the average hematocrit drop was from 33.6% to 26.8%. For two and three week old pigs chilled at the same temperature, the average hematocrit drop was only 0.6% and 1.2% respectively.

THE THYROID ACTIVITY OF VERY YOUNG PIGS AS DETERMINED BY THE TURNOVER OF RADIOACTIVE IODINE. H. W. Newland, L. F. Wolterink, R. W. Luecke, and W. N. McMillen. *Michigan State College.*

Iodine 131 (radio active, half life eight days) was injected into young pigs shortly after birth. Counts were taken over the thyroid region for periods up to 175 hours. Uptake of I^{131} by Duroc × Chester White crossbred pigs was found to be much more rapid than in Berkshire or Berkshire × Chester White crosses. Similarly the out-put curves showed more rapid turnover in the thyroids of the Duroc × Chester White crosses than in the Berkshire or Berkshire × Chester White pigs. The relationship of these observations to thyroid activity will be discussed.

THE EFFECTS OF ENVIRONMENTAL TEMPERATURE AND THE THYROID GLAND ON FERTILITY IN MALE RABBITS. Mohamed M. Oloufa, Ralph Bogart and Fred F. McKenzie, *Oregon State College.*

An experiment was conducted in the fall of 1948 and its duplicate was carried on in the spring of 1949 using mature male rabbits to study the effect of the thyroid gland and environmental temperature on fertility. Out of six groups included in the study one served as a control. From several semen characteristics and the histology of the testes, epididymides, and thyroid glands the following conclusions were drawn: High environmental temperatures reduce fertility, continuous heat being more detrimental to fertility than intermittent high and low temperatures. The addition of thyroxine is harmful to the animal when kept under continuous high temperature, while its administration to animals under intermittent high and low temperatures may alleviate some of the ill effects of the heat on fertility but will not give results equal to animals kept under cool temperature. Administration of thiouracil lowered fertility to a level intermediate between animals kept under continuous heat and those kept under intermittent high and low temperatures. All animals receiving thyroprotein lost weight. It is suggested that environmental temperature affects fertility directly by acting on the testis and indirectly by acting on the thyroid gland. Addition of thyroxine may alleviate the indirect action of temperature but would not alleviate the direct effect of high temperature on the testis.

PRELIMINARY STUDIES ON THE HISTOLOGY OF THE REPRODUCTIVE ORGANS OF STERILE COWS. D. B. Roark, R. C. Laben and H. A. Herman, *University of Missouri.*

A histological study of the genital organs of non-breeding cows was made to determine if observable changes in the tissues might throw light on the reason for sterility. From November 1947 to July 1949, twenty dairy cows were sold for slaughter from the University herd. Fourteen of these were classed as non-breeders. Tissue sections from the vagina, cervix, uterus, oviducts, and ovaries were studied to determine histo-pathological changes which might have taken place. Three of the animals which showed normal breeding histories served as controls. Immediately after killing, the entire genital tract was removed and given first attention. The organs were examined thoroughly and notations on the gross anatomy recorded. The tissues were placed in Bouin's fixative, subsequently dehydrated in alcohol, embedded in paraffin and sectioned at 8 to 10 micra. Delafield's hematoxylin, Mayer's hemalum, eosin and erythrosin were used for routine stains. Special stains used were Mayer's mucicarmine to demonstrate mucus and Wilder's silver impregnation technique for reticulum and collagenous fibers. Measurements of thickness of the epithelium and stroma were made with an eye-piece micrometer. Examination of organs revealed two cases of double external os, anterior to which was a single cervical canal. In four non-breeders, severe tubal and ovarian adhesions were found. Microscopic examination suggested acute to chronic salpingitis in two of three cases. Records of productive, reproductive and clinical histories are available for all cows. The records of non-breeders and of their close relatives were studied.

INBREEDING AND STRAIN INFLUENCES ON COMPONENTS OF FERTILITY IN SOWS. C. D. Squiers, E. R. Hauser, G. E. Dickerson and D. T. Mayer, *University of Missouri.*

In 1947 study of (1) age of puberty (2) ovulation rate (3) fertilization rate and (4) embryonic mortality was begun, using two strains inbred Poland, one of inbred Hampshire, outbred Durocs and their crosses. In general, gilts were bred once as soon as estrus was observed, alternating related and unrelated boars. Alternate animals in each breeding group were slaughtered at 24 hours post-estrus for ovulation and fertility rate and at 25 day for ovulation rate and mortality. Age at first estrus averaged 7 months, ranging from 7 to 8 months

for inbreds and 6 to 7 for non-inbreds. Ovulation rate for 214 gilts averaged 11.0. Strain and cross differences were significant, ranging from 10.4 to 12.0, but inbreds equalled crosses. The 48 older sows averaged 15.7, and ranged from 13.9 for inbred Hampshires to 17.8 for non-inbred Durocs. Left ovaries shed ½ more ova than right in gilts, but not in sows. Variation between sows in activity of right and left was much greater than in total ovulations, indicating alternation in activity levels. Four-fifths of ova were recovered at 24 hours. Of these, 93 percent were fertilized (cleaved). Total mortality to 25 days averaged 46 percent for gilts, consisting of 7 percent unfertilized ova, 28 percent very early mortality, and 11 percent partly decomposed embryos. Total mortality was similar, 43 percent, in older sows, but decreased significantly with age at service among gilts ($r = .33$, $b = -5.5$ percent per 10-day increase in age). Large intra-group variation ($\sigma = 33$ percent) makes difficult detection of group differences in fertility to 25 days.

THE RELATIONSHIP OF THE PERCENTAGE LIVE SPERMATOZOA IN DAIRY BULL SEMEN INITIALLY AND FOLLOWING COLD SHOCK TO OTHER SEMEN CHARACTERISTICS AND FERTILITY. E. J. Stone, J. E. Johnston and J. P. Mixner, *New Jersey Agricultural Experiment Station.*

It has been shown that staining semen with a Fast Green FCF-Eosin stain results in the differentiation of live from dead spermatozoa. The initial percentage of live spermatozoa in a semen sample and the percentage of live spermatozoa in an egg yolk buffer surviving a 0° C. cold shock for 10 minutes have been suggested as criteria for determining semen quality. In this report data on 236 semen samples from 18 dairy bulls have been utilized including data on 81 semen samples on which fertility data representing 20 or more services per sample were available (total of 2753 services). In addition to determining the initial percentage live spermatozoa and the percentage of spermatozoa in diluted semen surviving a cold shock the following semen characters have been determined and correlated with live spermatozoa data: semen volume, sperm concentration, no. of spermatozoa per ejaculate, initial motility rating, duration of "2" motility (undiluted semen), total duration of motility (undiluted semen) and total duration of motility (diluted semen). These intra-semen correlations will be presented on a total, between bull and within bull basis together with correlations between the measures of percentage live spermatozoa and fertility. Although the correlations with fertility have very little "prediction value" they may serve a useful purpose in the rapid evaluation of semen.

THE EFFECT OF IODINATED CASEIN AND THIOURACIL ON THE CAROTENOID METABOLISM OF THE PIG. R. W. Swick, R. H. Grummer and C. A. Baumann, *University of Wisconsin.*

Weanling pigs were depleted of vitamin A until the plasma concentration fell below 8 μg of vitamin A/100 ml. At this time certain individuals were rendered hyperthyroid by the incorporation of iodinated casein in the ration at levels ranging from .02 to .1% while amounts of thiouracil varying from .1 to .3% were fed to others to produce hypothyroidism. After the metabolic states were established, carotene or vitamin A was fed for 16 to 21 days, and the stores of vitamin A in the liver and kidneys were determined following this supplementation. Larger stores of vitamin A were found in the hyperthyroid animals fed carotene than in normal pigs except when the level of iodinated casein was high enough to cause diarrhea. The hypothyroid pigs stored slightly larger amounts of vitamin A when given carotene than did the normal animals. Similar reserves of vitamin A were observed in all groups given preformed vitamin A. The administration of a large amount of carotene or vitamin A 6 to 7 hours before slaughter produced a marked increase in the concentration of vitamin A in the mesenteric lymph and a smaller rise in vitamin A content of the blood plasma and intestinal wall of these pigs. Thus, conversion of carotene into vitamin A in the intestinal wall of the pig has been confirmed.

THE EFFECTS OF PROGESTERONE UPON OVARIAN FUNCTION IN GILTS.

L. C. Ulberg, R. H. Grummer and L. E. Casida, *University of Wisconsin.*

Twenty gilts were divided into groups of five and injected with progesterone. Four dosage levels were studied: 12.5, 25, 50 and 100 mg. daily given subcutaneously. Injections were started 14 days after the beginning of a heat period and were continued up to the 28th day if no heat was shown. If a gilt came into heat she was slaughtered 24–48 hours after the end of heat. If no heat was shown she was slaughtered 7 days after the end of treatment. When the three higher dosage levels were used, heat was suppressed in all gilts during the treatment interval. When 100 mg. were injected the gilts came into heat approximately 6 days after the end of treatment. The ovulation from this heat was apparently normal. When 50 mg. were injected heat and ovulation were suppressed during and after treatment in 4 out of 5 gilts and at slaughter the follicles of these gilts were found to be cystic, ranging in size from 20–50 mm. in diameter. The fifth gilt in this group reacted similar to gilts receiving 100 mg. daily. When 25 mg. were injected daily 4 gilts came into heat 3–5 days after end of treatment and on slaughter they were found to have ovulated. The fifth gilt of this group showed no heat but had cysts and corpora lutea at slaughter. 12.5 mg. daily had no apparent effect on 4 out of 5 gilts. The fifth gilt came into heat 5 days after end of treatment, but had not yet ovulated 24–48 hours after end of heat.

THE AGE AT PUBERTY IN A HERD OF INBRED SWINE.

A. C. Warnick, E. L. Wiggins, L. E. Casida, R. H. Grummer and A. B. Chapman, *University of Wisconsin.*

One hundred thirteen gilts were checked daily with a vasectomized boar to determine first heat. Checking began at 5½ months of age. The number of gilts in each line, the average age at first heat, and the average weight at first heat were as follows: Line 1, 18 animals, 226 days, 171 lbs.; Line 2, 31 animals, 228 days, 167 lbs.; Line 3, 17 animals, 236 days, 178 lbs.; Line 4, 24 animals, 242 days, 200 lbs.; Line 5, 23 animals, 243 days, 165 lbs. There were significant differences between lines in the weight at first heat, but not in the age at first heat. Significant differences between lines occurred in the number of corpora lutea at both first and second heat periods. Associations between time of farrowing, weight at 56 days and weight at 154 days with age at first heat were found. Forty-one boars were checked for puberty (first mating) with an estrogenized gilt beginning at 5½ months of age. The number of boars in each line, the average age and the average weight at puberty were as follows: Line 1, 9 animals, 196 days, 168 lbs.; Line 2, 11 animals, 186 days, 170 lbs.; Line 3, 8 animals, 171 days, 154 lbs.; Line 4, 5 animals, 203 days, 187 lbs.; Line 5, 183 days, 143 lbs. Significant differences existed between lines in the age but not in weight at puberty.

CYCLIC HISTOLOGICAL CHANGES OCCURRING IN THE ENDOMETRIUM OF THE VIRGIN HEIFER.

Alvin F. Weber and Banner Bill Morgan, *University of Wisconsin.*

The histology of the endometrium was studied in 33 virgin heifers slaughtered at intervals to include all days of the cycle. A statistical study of cyclic changes in epithelial height together with histological observations suggested that the uterine glandular epithelia did not regress until immediately before the following estrus. Interstitial tissue degeneration was not found to occur, and vascular changes during the period 13 to 19 days postestrus were considered to be insignificant. It was impossible to demonstrate secreted substances in the uterine glands or in the uterine lumen. The lymphocyte infiltration that followed the increase of neutrophiles began about the 3rd day postestrus and completely receded by the 7th day postestrus. Eosinophils were found to be uniformly scarce in the endometrium, with one exception. Lymphoid nodules were rarely found in the endometrium, except in two heifers. Plasma cells were uniformly scarce, except in those cases where lymphoid nodules were present. The uteri of these two heifers were considered abnormal.

MINIMAL NUMBER OF SPERM FOR FERTILITY IN ARTIFICIAL INSEMINATION OF SWINE. E. L. Wiggins, R. H. Grummer and L. E. Casida, *University of Wisconsin.*

Forty-one gilts and 14 sows were inseminated 12–24 hours after the beginning of heat with varying quantities of fresh semen diluted to a standard volume of 50 cc. in Krebs solution. All animals were slaughtered 24–36 hours after the end of heat to determine fertilization. In gilts the volumes of semen, the numbers of animals and the average percentages (unweighted) of fertilized eggs were as follows. 0.01 cc., 2 animals, no fertility; 0.1 cc., 5 animals, 33% fertility; 1 cc., 10 animals, 40%; 5 cc., 9 animals, 50%; 10 cc., 5 animals, 60%; and 20 cc., 10 animals, 91%. Ten sows inseminated with 1 cc. of semen had an average fertility of 39%. Only 4 sows have thus far been tested on 20 cc. and these had an average fertility of only 51%.

THE REPRODUCTIVE PERFORMANCE OF TWO SELECTED LINES OF HAMPSHIRES, R. F. Wilson, A. V. Nalbandov and J. L. Krider, *University of Illinois.*

The reproductive efficiency of two lines of Hampshires bred for rapid and slow gain in weight is compared with that of females from an unselected population consisting of six breeds. It was found that the rapid line ovulated more eggs than the slow line, that more fertilized eggs became embryos in the rapid line but that about the same average number of pigs per female was farrowed in the two lines. The study is still in progress and the data to be presented are not final. The reproductive loss from ovulation to farrowing in both lines combined was about 50%, a loss which is greater than that observed in unselected populations of swine. Cystic follicles were found in 11.5% of the "normal," and in 25% of the "hard to settle" Hampshires from the two lines. In "hard to settle" females from the unselected population cystic follicles were found in 10.1% of the cases. It was possible to predict the presence of cystic follicles in living females because of certain behaviouristic peculiarities, irregularities of their estrual cycles and, in about 40% of the cystic females, because of the enlargement of their clitoria. Hydrosalpinges were found in 3.8% of the "normal," and in 5.0% of the "hard to settle" Hampshires, while 21.5% of the animals from the unselected population had this abnormality.

EFFECTS OF NUTRITIONAL DEFICIENCIES IN RATS ON RESPONSE OF THE GONADS AND ACCESSORIES TO A CONSTANT DOSE OF PREGNANT MARES' SERUM. K. B. Yadu and Joseph Meites, *Michigan State College.*

Hertz (1948, 1949) has recently shown that folic acid deficiency in chicks, rats or monkeys can inhibit the normal response of the oviduct or uterus to estrogenic hormone stimulation. The present experiments were undertaken to determine whether or not any particular nutritional factor was essential for the growth and secretory response of the gonads and accessories to gonadotrophic hormone stimulation. Weanling albino rats of both sexes were fed a standard semi-synthetic diet for a 28-day period, and during the last 4 days were injected with a constant dose of pregnant mares' serum. Deficiencies were induced in the diet either by omitting a particular vitamin, by the inclusion of certain vitamin antagonists, or by reducing the protein, fat or caloric content. Preliminary results indicate that deficiencies of the following do not affect the gonadotrophic response: vitamins A, D, thiamin, B_6, panthothenic acid, protein, fat and total caloric intake. Deficiencies induced by omitting riboflavin from the diet, or by adding a folic acid antagonist or sulfasuccidine, appear to inhibit the gonadotrophic response. The relation of these data to animal breeding problems will be discussed.

NEWS AND NOTES

The forty-first annual meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago, Illinois on November 25 and 26, 1949, with a dinner for the honored guest on November 27. Abstracts of all submitted papers which are to be presented at the meeting are published in this issue of the JOURNAL OF ANIMAL SCIENCE. Reprints of the Abstract Section of this issue of the JOURNAL will be available to members at the annual meeting.

The nominating committee of the American Society of Animal Production with W. A. Craft as Chairman has prepared the following slate of officers for consideration by the Society at its annual business meeting in Chicago on November 26:

For President—
P. S. Shearer
Iowa State College

For Vice-President—
E. H. Hughes
University of California, Davis
E. W. Crampton
Macdonald College, Canada

O. E. Reid, Chief of the Bureau of Dairy Industry, attended the Dairy Congress held in Stockholm, Sweden, August 15 to 19, as Chairman of the delegation from the United States.

Alvin L. Neumann has returned to the University of Arkansas as Professor of Animal Industry. He has recently completed his Ph.D. degree at the University of Illinois.

P. B. Doby, who has just received his BSA and DVM degrees from Kansas State College has become Assistant Professor of Animal Industry and Assistant Veterinarian at the University of Arkansas. He will conduct research on artificial breeding of dairy cows.

Dwight L. Espe has joined the staff of the Office of Experiment Stations, U.S.D.A. as Experiment Station Administrator (Dairy Husbandman). He was formerly with the Iowa and North Dakota Agricultural Experiment Stations.

The United Nations Scientific Conference on Conservation and Utilization of Resources was held at Lake Success, New York, from 17 August to 6 September, 1949. A wide range of subjects was dealt with in this Conference, many of which were of interest to animal husbandry workers, and a number of the members of the American Society of Animal Production participated by preparing and in some cases presenting papers. These included Hugh C. McPhee of the U. S. Bureau of Animal Industry; Ralph W. Phillips of the Food and Agriculture Organization of the United Nations; J. L. Lush of Iowa State College, George H. Hart of the University of California; Albert O. Rhoad of the Inter-American Institute of Agricultural Sciences, and John Hammond of Cambridge University.

Ralph W. Phillips of the Food and Agriculture Organization of the United Nations was in Europe and Africa during late September, October and early November, where he participated in a meeting of the FAO European Committee on Agricultural Technology in Rome, and also visited Cairo and Addis Ababa on behalf of FAO. He also attended an African Regional Research Conference in Johannesburg, and the Fifth International Animal Production Conference in Paris.

Arthur T. Semple of the Food and Agriculture Organization of the United Nations spent five weeks in Guatemala during July and August, giving advisory assistance to the Government of that country on its beef cattle and range and pasture improvement programs. During late September, October and November, Mr. Semple has been traveling in Southeastern Europe and Northern Africa on behalf of FAO, and participated in two technical conferences

in Nigeria, dealing with land utilization and idigenous rural economy problems in Africa, which were sponsored by the British Government.

A publication entitled "Sheep Farming Annual—1948" was issued recently by the Massey Agricultural College, Palmerston North, New Zealand. This publication includes the proceedings of the Eleventh Annual Meeting of Sheep-farmers held at the College in June 1948, and contains chapters on most of the problems connected with the sheep industry in New Zealand. The price is 10 shillings.

W. G. Kammlade has been appointed Associate Director of Extension at the University of Illinois.

R. M. Forbes has been appointed Associated Professor in Animal Science at the University of Illinois.

A. A. Heidebrecht, Assistant Professor of Animal Husbandry at Oklahoma A & M College, has been appointed as Director of the college's Swine Husbandry work.

R. F. Wilson, formerly a member of the Department of Animal Science at the University of Illinois, has been appointed Swine Specialist at South Dakota State College of Agricultural and Mechanical Arts.

Erratum. In the last issue of this JOURNAL, Walter Armer of Arizona and H. H. Mayo of Indiana were erroneously reported to be on foreign assignments in Greece. The item should have stated that they were members of educational-tour parties sponsored by Swift and Company.

Walter H. Peters, head of the animal husbandry department, University of Minnesota, and honor guest of the "Society" at its last annual meeting, departed this life after a long period of illness, on August 8, 1949.

George H. Haines, long-time animal geneticist on the staff of USDA's Office of Experiment Stations, and in retirement for several years on account of physical disability, recently died at his home in Hyattsville, Maryland.

W. H. Black, director of the Front Royal (Va.) Beef Cattle Breeding Research Station, and for many years head of beef and dual-purpose cattle investigations for the U. S. Department of Agriculture, died at Georgetown Hospital in Washington, D. C. on July 23, 1949. A. L. Baker, superintendent of the New Iberia Experiment Station at Jeanerette, Louisiana, and formerly on the staff at the U. S. Range Livestock Experiment Station, Miles City, Montana, succeeded Mr. Black in charge at Front Royal on September 20.

A. D. Weber, head of the animal husbandry department, Kansas State College, and former president of the American Society of Animal Production, served as judge of Hereford breeding cattle at Palermo Park, in Argentina, at their National Livestock Exposition held in August. Dr. Weber also will again serve as judge of the individual steer classes at this year's International Live Stock Exposition in Chicago.

Leslie E. Johnson, former head of the animal husbandry department at South Dakota State College, became regional director of the North Central beef-cattle breeding project for the U. S. Bureau of Animal Industry and cooperating State experiment stations of the region on September 1, 1949. Dr. Johnson is making headquarters at the University of Nebraska, Lincoln.

Carl P. Thompson, veteran swine expert of Oklahoma A. and M. College, after 31 years' service on its animal husbandry staff, was assigned administrative duties by President Bennett of the College effective last July. Dr. Thompson's new duties will include cooperation with institutions and agencies in the field of secondary and junior college agricultural education.

Clair E. Terrill, of the U.S.D.A. Staff at the Western Sheep Breeding Laboratory, Dubois, Idaho, spent 90 days in Australia and New Zealand this fall studying technological services in special uses for wool and other activities which would be of value to American wool growers.

Conrad A. Elvehjem, of the University of Wisconsin was honored by the National Live Stock and Meat Board at its 1949 annual meeting by being awarded a certificate of recognition for his contribution to the science of biochemistry and his leadership in the field of nutrition.

Paul E. Howe, nutrition specialist in the U. S. Bureau of Animal Industry, spent several months in Europe this summer and fall on a nutrition mission for the Department of the Army.

A. L. Shealy, head of the animal industry department, University of Florida, announced his retirement, effective August 31, 1949, to enter private veterinary practice at Gainesville, Florida. By reason of his 30 years' service on the University faculty, Dr. Shealy was given the title of emeritus professor.

Clifford M. Hardin, has been made director of the Michigan Agricultural Experiment Station, succeeding V. R. Gardner, retired.

Ralph L. Watts, dean of the School of Agriculture, Pennsylvania State College, from 1912 to 1939, and since retirement serving in an emeritus capacity, recently died.

J. Earl Coke, former 4-H Club member, and County Agricultural Agent, and more recently holding an executive position with a sugar corporation, was appointed director of agricultural extension, University of California to succeed B. H. Crocheron, deceased, effective July 1, 1949. C. W. Rubel has been acting director since 1948.

Paul M. Grinde, animal husbandry graduate of Rutgers University and Air Corps veteran was appointed extension associate in animal husbandry for the New Jersey College of Agriculture, effective July 1, 1949.

A. J. Reed, former extension dairyman, University of Nevada, was given the title of extension animal husbandman on July 1, 1949, and made responsible for all extension work with farm animals in that state.

Joe V. Whiteman, wool marketing specialist and Robert D. Rasmussen, associate animal husbandman, in the New Mexico Agricultural Extension Service, both resigned recently, the former to pursue graduate work at the Oklahoma A. and M. College, and the latter to become assistant professor of animal husbandry at Arizona State College, Tempe.

Forrest G. Ketner, general manager of the Producers' Livestock Cooperative Association at Columbus, Ohio, was elected chairman of the National Live Stock and Meat Board at its recent annual meeting held in Chicago.

N. R. Ellis, of the animal husbandry staff at the Agricultural Research Center, Beltsville, Maryland, attended the International Grasslands Conference and made other contacts in Europe this past summer.

Forrest R. McClain, Oklahoma A. and M. graduate and recently on the animal husbandry staff, University of Tennessee, has been appointed associate extension animal husbandman, Louisiana Agricultural Extension Service, to succeed Harry P. Gayden, resigned.

Walter Biggar, of Dalbeattie, Scotland, who judged the individual steer classes at the International Live Stock Exposition at 13 shows during the 1920–1946 period, died on June 24, 1949.

Charles R. Kyd, extension animal husbandman, University of Missouri, is on sabbatic leave for a year while pursuing graduate study at Purdue University.

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